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ACKNOWLEDGEMENT

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Washington, D. C. 20250

1380(4000)

Mr. Robert W. Long
Assistant Secretary
U.S. Department of Agriculture
Washington, D. C. 20250

Dear Secretary Long:

I am pleased to send to you Forest Service Research Accomplishments/1974.

This year's report again illustrates the many ways in which the Forest Service is working to help the Nation solve forestry problems, including environmental and energy problems. The report includes research that can be applied by a wide segment of the public, including timber owners, forest product industries, urban foresters, natural resource managers, land use policy makers, and homeowners.

We also feel the information provided in this report will be of equal benefit to other resource agencies, both within the Department and in other branches of Government.

We are continually striving for a research program aimed at solving the critical problems faced by public and private resource managers. A broad overview of the major steps taken to improve management and protection of America's natural resources is highlighted in this report.

Sincerely,

John R. McGuire

JOHN R. McGUIRE
Chief

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U.S. DEPARTMENT OF AGRICULTURE

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FOREWORD

Forest Service research plans are coordinated through the Assistant Secretary for Conservation, Research and Education with research in other USDA agencies, with that conducted under the Hatch Act at land grant institutions, and with that conducted under the McIntire-Stennis Act at schools of forestry.

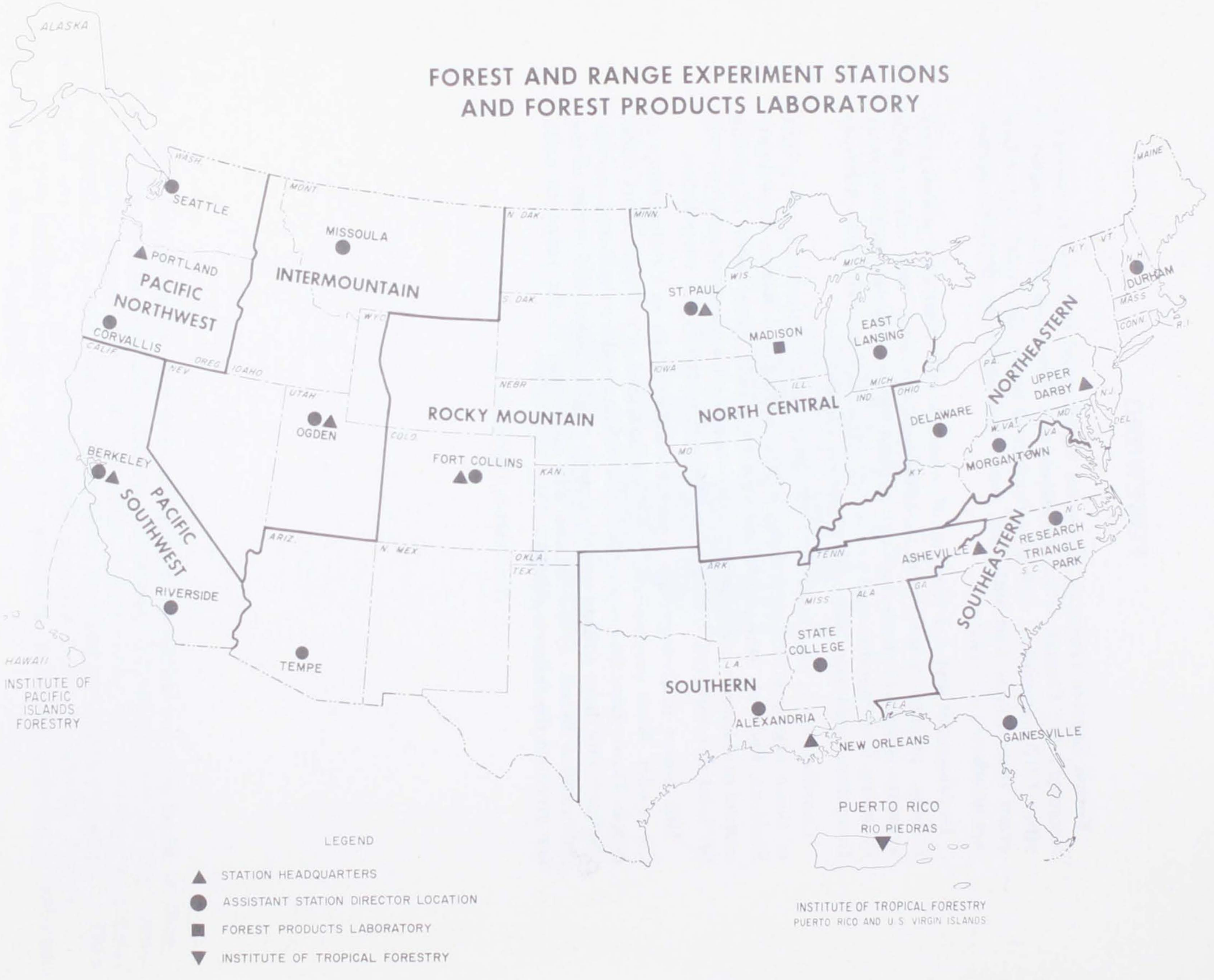
Development and coordination of research with other educational institutions, private enterprises, nonprofit institutions, and other public agencies is done through the Regional and National Agricultural Research Planning Program directed by the Agricultural Research Policy Advisory Committee and the National Planning Committee.

Coordination is also maintained through direct contact between people of these organizations and those of the Forest and Range Experiment Stations. Federal, State, industry, and university cooperation in solving mutual problems is achieved through cooperative agreements that provide for joint development and support of the research by the cooperators.

This report is arranged by research subject areas as a convenience to the reader. Each accomplishment is summarized in a single, short paragraph. Throughout this report an abbreviation signifies the Forest Service research unit best able to supply detailed information and copies of the publications listed. Abbreviations and addresses of the research units are given on the following page.

Issued August 1976

FOREST AND RANGE EXPERIMENT STATIONS AND FOREST PRODUCTS LABORATORY



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Intermountain Forest and Range Experiment Station
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Rocky Mountain Forest and Range Experiment Station
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North Central Forest Experiment Station
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I. IMPROVING ENVIRONMENTAL QUALITY, PRODUCTIVITY, AND USEFULNESS

A. Reducing Pollution

1. Controlling soil erosion

1. Erosion is an increasing problem in Hawaii. Municipalities are expanding onto steep mountains and into forests. Forests are being converted to improve timber production. Recreational use extends into once primitive areas. Soil losses under simulated rainfall were used to relate erosion to erodibility for soils collected on the Koolau and Waianae Ranges. Variation between samples in maximum rates of erosion were related to organic matter content and bulk density of the soil. The results suggest that soils derived from ash and basaltic colluvium will require more careful management than basaltic soils. RM(10).

2. Soil ripping is an effective, but temporary, measure to control runoff and erosion on semiarid watersheds. Its effectiveness normally lasts 3 to 5 years. Re-ripping previously treated areas in New Mexico was highly successful in extending treatment effectiveness until vegetation could become established. Re-ripping reduced runoff by two-thirds. In all instances, ripping must be done carefully to avoid subterranean channel formation (erosion by soil piping). RM(1).

2. Chemicals in the forest environment

3. TCDD, a toxic dioxin contaminating 2,4,5-T formulations, may enter streams following spraying to control brush. The toxicity of this chemical to aquatic organisms was investigated. Exposure for 24 to 96 hours of young salmon to TCDD in water at levels greater than 23 ng/g produces irreversible effects and death results in 10 to 80 days. The critical exposure period in static water is less than 24 hours. TCDD in food at 2.3 ppm markedly reduced growth and survival of young rainbow trout after 4 weeks. TCDD at 0.2 ppb in water had no effect on pupation of mosquito larvae, but it reduced the reproductive success of two other benthic species, pulmonate snails and an Oligochaete worm. The minimum threshold response levels for TCDD in water to fish have not been firmly established, but results of this test suggest they will be somewhat higher than levels of TCDD expected to occur in forest streams after spraying with 2,4,5-T. PNW(12).

4. Cacodylic acid is used for precommercial thinning in western forests, but careless handling and application can unacceptably expose applicators to arsenic in the chemical. During a 2 month study, sponsored by the Pacific Northwest Forest and Range Experiment Station, healthy workers were exposed to cacodylic acid and observed for evidence of arsenic accumulation in blood, the pattern of urinary excretion of arsenic, and signs of clinical toxicity. Urinary arsenic provided an adequate index of exposure. Excretion levels increased within one week, but amounts in blood and urine did not exceed presently acceptable levels. The study emphasized the need to educate workers in proper safety precautions when handling this toxicant. PNW(14).

5. Picloram applied to control brush on a small experimental watershed in central Arizona was detected in stream water during the first 3 months after treatment. After 14 months and 40 inches of accumulated rainfall, picloram was no longer detected. An estimated 4.5 percent of the chemical passed into the stream. Direct use of stream water during the first 3 months after spraying could have damaged sensitive crops such as cotton; therefore managers must be careful to allow for adequate downstream dilution. RM(11).

6. Trees growing on soils heavily contaminated from past, heavy applications of lead arsenate insecticide are severely stunted and fail to respond to fertilizers. Rootlets of affected trees are generally poorly developed, and mycorrhizal frequency is low. Mycorrhizae are essential for adequate nutrient uptake by woody plants. The mycorrhizal deficiency in high arsenic soils could account for the lack of response by stunted trees to fertilizers. PNW(344,546).

3. Air pollution

7. Forest managers and ecosystem modelers have urgent need to know the relative susceptibility of western conifer species to air pollutants. Twelve selected species and two pine hybrids were subjected to ozone fumigations of up to 480 hours. Ponderosa, Jeffrey, and Coulter pines and white fir were all moderately susceptible while sugar pine and incense cedar were tolerant. These are the major species in the western mixed conifer forest now damaged. Strategies for replanting and stand management can begin to be developed from these results. PSW(353).

8. Successional trends in the oxidant-damaged mixed conifer forests of southern California must be identified to provide forest managers and ecosystem modelers with the information needed for selection of management alternatives and modeling strategies. Age composition and species distribution on different sites were determined for conifers on a heavily damaged 575-acre area. Ponderosa pine was dominant in the overstory, but on moister, north-facing slopes white fir was more frequent. Mortality of overstory ponderosa pines was 10 percent during a 4-year period and insignificant for other species. Incense cedar was most abundant in the understory. Tolerant sugar pine comprised less than 10 percent of overstory and understory. Chronic exposure to oxidant air pollution is hastening succession from a diverse mixed conifer forest dominated by ponderosa pine to a less desirable forest composed of incense cedar, white fir, and woody shrubs. PSW(352).

9. It is difficult to diagnose the precise cause of injury to forest trees where multiple air pollutants prevail, and especially when winter injury might be involved. Scientists in California studying the reaction of pines to sulfur oxides, ozone, smog, and winter injury have revealed some diagnostic clues in the internal makeup of needles which will help determine the cause of injury. PSW(348).

10. The impact of chronic air pollution to timber growth is difficult to evaluate. Measurements of ring width and wood

density at breast height do not correlate well with foliar symptomatology in ponderosa pines damaged by chronic exposure to oxidants in southern California. Improved sampling procedures should involve analysis of ring width at each internode, and variations due to precipitation must be nullified by cross-dating ring analyses with precipitation records. The development of accurate procedures to evaluate the impact of pollution is a necessary step in the protection of our Nation's natural resources. PSW(351).

11. The impact of air pollution to a total forest ecosystem is not well documented. Identification and quantification of the long-term effect of oxidant air pollutants on primary producers, consumers, and decomposers in the mixed conifer forest ecosystem of southern California is being attempted through systems modeling. The desired result is to develop techniques for predicting the long-term consequences to the forest ecosystem. Such predictions are needed to formulate management systems and to set workable air quality standards. PSW(354).

12. Commercial production of Christmas trees in the Appalachian regions of Maryland and West Virginia has steadily deteriorated because of excessive damage from air pollution. A description of the nature and extent of ambient pollutants on these conifer farms and information on the production and selection of evergreen species tolerant to ambient phytotoxic pollutants has been provided to Christmas tree growers in the Appalachians. NE(347).

13. The reduction in growth and yield of forest trees that results from low levels of air pollutants is unknown. A chamber used to measure gas exchange in forest tree seedlings was developed and employed. Growth of sugar maple, silver maple, and sycamore seedlings was significantly reduced by 30 parts per hundred million (pphm) ozone after 5 months of exposure. This information about the growth of seedlings in the presence of ozone will aid in the evaluation of the impact of aerial pollutants on forest woodlands. NE(349,350).

14. Air pollution causes severe harm to forest ecosystems throughout the world. In Poland, cooperative research has demonstrated that economic losses are increased by interactions of forest insects with trees weakened by air pollution. Some of these losses can be reduced through sanitation practices, biological control of insects, use of tolerant trees, and improved land-use planning. NE(355,356).

15. There are many problems in testing for tolerance of forest trees to air pollution. Research has proved that age of seedlings and plant tissues determine relative susceptibility of various pine species to different air pollutants. This discovery that age influences susceptibility of pine seedlings to air pollutants is extremely valuable to the development of resistant lines of various forest tree species to different air pollutants. SE(345).

16. Sulfur dioxide, fluorides, and oxidants cause major air pollution damage to trees throughout the United States. Field exposures of potted seedlings demonstrated that certain selections of eastern white pine are differentially sensitive to these air pollutants. Selections from sensitive trees are being propagated for use as specifically sensitive bioindicators of air pollution. Resistant lines are also being propagated for use in seed orchards of white pine. Release of these new lines will enable white pines to be grown in areas with unavoidable moderate levels of air pollutants. SE(346).

4. Recycling wastes--sewage effluent sludge and residues

17. Economical treatment and disposal of sewage effluent accompanied by protection of water and land resources is a necessary but difficult goal now sought by communities throughout Michigan and other states. Disposal of sewage wastes on forest land is a possible route to the attainment of this goal, but evaluation and verification tests are needed. Irrigation of a 25-year-old jack pine plantation on a very sandy soil in central Michigan with treated sewage effluent significantly increased diameter growth of dominant trees by the end of the first growing season. Irrigation at the rate of 65 mm (2.5 inches) per week resulted in nitrate-nitrogen increases in groundwater at depths of 3 m (10 feet). Concentrations of phosphorus in groundwater were unchanged. Public health considerations may limit the permissible dosage levels in such highly permeable soils. Further tests are suggested to determine whether other vegetation types may be more satisfactory for sewage renovation purposes on extremely sandy soils. NC(17).

18. Mineral-enriched sewage effluents can disrupt aquatic environments and may also pose problems when applied to land. In north-central Pennsylvania an effluent was applied at the rate of 2 inches a week during six growing seasons. Growth of red pines was slightly decreased after the first 2 years; whereas, an application of 1 inch per week significantly increased growth. Applications of either 1 or 2 inches per week greatly increased the growth of white spruce and hardwoods. Corn crops annually took up more nutrients (N, P, K, Ca, Mg) than the hardwood forest. During the winter forests provided better infiltration conditions than cropland. A combination of cropland and forestland was found to provide maximum flexibility for year-round land application of sewage effluent. NE(16).

19. Changes in soil chemistry have occurred during 7 years as sewage wastewater has been applied to woodlands in north central Pennsylvania. Treatments increased exchangeable Mg, Na, and Cations (mostly in the upper soil zone), they had little effect on exchangeable K and H, and they increased exchangeable Mn in the deeper layers. The small changes that have occurred appear to pose no problems for the future. NE(15,547).

B. Improving Wildland Animal Habitats

1. Mammal-bird-livestock-vegetation relationships

20. The abundance of deer in loblolly-shortleaf pine forests, from Virginia to east Texas and Oklahoma, depends largely upon how pine and hardwood timber stands are managed. Several investigations have provided practical management guidelines. These permit forest managers to improve habitats for white-tailed deer while maintaining or improving timber production. Deer food, and thus deer herds, can be increased by retaining hardwoods along drainageways, prescribed burning, regulating size, shape, and distribution of cutting units and favoring desirable food plants. SO(121).

21. Many wild plants, called weeds, provide important sources of food to birds in southern forests. Managers up to now have not been able to distinguish the importance of weeds in the spurge family to wild birds. A list including illustrations and recommendations for improving fruit yields of selected species has been made available to managers of forests on the Gulf Coast. SO(122).

22. Forage yields on forest range vary with stand age and timber management regime. Managers need information to predict grazing capacities throughout timber rotations. A

study was made in central Louisiana to disclose responses of herbage in longleaf pine plantations that were thinned and burned. Results show that maturing stands, if burned and thinned regularly, can provide substantial quantities of forage for cattle and deer in addition to good timber yields. Also, the grassy understories provide good range for bobwhite quail and create attractive hunting opportunities. SO(119).

23. Investigations in central Louisiana have been summarized to show costs and returns from forest grazing. Prescribed rotational burning, supplemental feeding, crossbred cows, good bulls, and regulated breeding seasons, when judiciously combined, provided good returns from forest range investments. Income from beef sales was particularly advantageous to timber landowners during years prior to commercial harvest of trees. Light grazing produced highest per-animal returns, while heavy grazing netted the greatest return per acre. None of the grazing intensities—light, moderate, or heavy--were detrimental to herbage yields. These results indicate that cooperation between cattlemen and timbermen can make forestry and grazing a profitable and compatible business. SO(128).

24. A new bibliography lists 950 important references about rangelands in the South. Livestock, wildlife, and management of this vast resource are included. This list of publications issued between 1968-1972 is a reference aid to land managers concerned with southern forest ranges. SO(129).

25. As wildland in South Florida is developed, managers want to know how to sustain huntable populations of bobwhite quail. Results from several studies have been summarized to provide management guidelines. A strip of native vegetation should be alternated with a strip of improved pasture or widely planted pines. In South Florida a variety of maintenance practices, including burning, deferred grazing, and disking, are recommended to rejuvenate ranges for quail. SE(126).

26. Persons interested in the vertebrate fauna of the San Joaquin Experimental Range in California now have available a revised check list. Nineteen new species have been added to the list. Seven fishes, eight amphibians, 19 reptiles, 38 mammals, and 149 birds inhabit the area. The check list gives additional references, common and scientific names of the species, its abundance and general location. This list will have special value to researchers, land managers, educators, and environmentalists interested in this and similar regions of the foothills of the Sierra Nevada. PSW(127).

27. Knowledge of the effects of fire on vegetation is basic to planning ecologically sound resource management. Researchers at Provo, Utah, documented vegetational changes following wildfire in the pinyon-juniper type. They found that weedy annuals reach their peak after 3 to 4 years. Juniper woodlands were well established 85 to 90 years following the fire. This finding supports earlier speculation that frequent fire restricted the spread of pinyon-juniper and enables resource managers to predict rates of change in vegetation following fire. INT(116).

28. Many sagebrush and pinyon-juniper ranges in Utah and adjoining states are depleted or unproductive. Techniques are needed to accurately assess ranges with the highest potential for improvement. Scientists have developed a method for determining quickly the productive potential of an area. This information can be used by resource managers to determine the feasibility of treating an area. INT(123).

29. Deer populations in Arizona have declined since 1960. Generalized regional descriptions of deer food habits had only limited usefulness for local wildlife management and land use planning in Arizona chaparral and desert habitats. Scientists used seasonal diets and their nutritional values to estimate nutrient intake of deer in these areas. These data are the basis for management prescriptions to improve deer range and population conditions. RM(125).

30. Chaparral occupies more than 4 million acres in central Arizona. Brush control is a prominent part of chaparral management. A study of impacts of these control programs (brush eradication by root plowing) on deer revealed that deer consistently used treated areas less than untreated brush fields. Researchers recommend that control areas be long, narrow and dispersed. RM(131).

31. During the past 30 years sagebrush has been controlled on 5 million acres in the West. Effects of controlling sagebrush on behavior of elk have not been known. Scientists in Wyoming reported that elk did not change their calving or feeding behavior when 96.7 percent of the big sagebrush was killed. Elk continued to use an area that had been treated with 2 pounds per acre of 2-4-D. It appeared that chemical control of sagebrush, if confined to limited and scattered areas, has no detrimental impact on elk during calving. RM(132).

32. Rocky Mountain researchers found that elk and cattle are socially compatible on ranges which produce sufficient food for both species. Elk preferred to maintain a distance of 300 yards from vehicle traffic on an interstate highway and about 1/2 mile from travelers on foot. Vehicle traffic had little effect on elk behavior. In planning for recreational facilities in elk habitats, concentrations of people should be kept 1/2 mile from elk feeding areas and adequate vegetative cover should be provided in the buffer area. RM(133).

33. Knowledge of the species of plants consumed by mule deer is basic to appraising, planning, and improving habitats. Researchers at the Rocky Mountain Station summarized data from 99 studies of food habits to assist managers in preserving and encouraging plants preferred by mule deer. The relative importance to mule deer of 202 shrubs and trees, 484 forbs, 84 grasses, sedges, and rushes, and 18 lower plants was presented. These ratings will guide managers in providing desirable forage. RM(124).

34. Sherman big bluegrass, a native species in the Rocky Mountains, is a valuable forage grass for livestock. Range managers have problems maintaining adequate stands of this grass because grazing livestock frequently pull up newly established plants. Results from laboratory experiments indicate that application of nitrogen fertilizer substantially increased root weight and the amount of tension required to lift plants from the soil. Fertilizer also increased foliage and shoot growth. If responses are similar under field conditions, applications of fertilizer may help maintain satisfactory stands of bluegrass. RM(120).

35. The effects of herbicides, especially 2, 4-D, on alpine plant communities has received little attention. These high mountain areas provide important sources of forage for livestock and wildlife. Range managers need methods to improve forage quantity and quality in these areas. Scientists at the Rocky Mountain Station found no significant change in the grazing capacity of sprayed areas, but there was an increase of grass and a decrease in forbs following spraying. RM(130).

36. Impacts of logging were studied on summer ranges of big game in the Pacific Northwest. Elk and deer were attracted to clearcuttings in mixed conifer forests because of the abundant growth of forage. Partial cuts, lacking a volume and variety of forage and cover for hiding were not heavily used. Use by animals indicated preference for uncut areas for cover, and clearcut areas for feeding. PNW(117).

37. Little is known about the benefits that yellow-bellied sapsuckers may provide by feeding on insects that harm trees, primarily because of the difficulty of locating birds in their natural habitat in the northern United States. A researcher in Maine has developed a calling technique for attracting these woodpeckers—it consists of tapping two hardwood dowels to imitate drumming and feeding noises. Using this technique, survey methods were developed for estimating population and delineating individual territories of these birds. NE(548).

2. Characteristics and values of forage or browse plants

38. Fruits of native plants in southern forests are important sources of food for wild birds and mammals. Wildlife managers need to know when native plants bear fruit and how much they yield. The flowering and fruiting characteristics are described for common woody vines, shrubs, and small trees. Using these guides, wildlife managers in the southern pine forests can select and manage fruit producing plants most useful to wildlife. SO(140).

39. Managers of deer herds in southern pine-hardwood forests need to know the quantity and quality of available food. Digestability is an important part of determining forage quality. A technique was developed to estimate digestibility of plants eaten by deer. Use of this technique will allow wildlife managers (1) to accurately estimate digestibility of plants over a wide range of ecological conditions and (2) to reduce the costs of conducting digestion trials with live animals. SO(148).

40. It is well known that herbage on bluestem ranges diminishes as density of pines increases. However, changes in botanical composition and chemical content of herbage during early development of southern plantations have not previously been documented. As cover provided by planted longleaf or slash pines increased in density, herbage protein and phosphorus increased while nitrogen-free extract decreased. The proportion of big bluestem, a preferred tall grass, increased faster under pine overstories than on cutover range. These findings provide managers with supplementary guidelines for predicting carrying capacities of forest ranges throughout timber rotations. SO(149).

41. Burning of forest range enhances forage quality, but frequencies and patterns of fires to optimize nutritive value have not been fully determined. In central Louisiana seasonal prescribed burns in winter, spring, and summer maintained higher nutritive content of bluestem herbage than winter fires only. Gains by Brahman crossbred heifers during the growing season were no greater on the seasonal burns than on the winter burns. SO(139).

42. Information on management of 100 shrubs and woody vines important to wildlife in the Northeast has been pulled together in a new technical report. The distribution, habitat, uses, and propagation of each species is discussed. This summary is a valuable reference to those interested in providing more favorable habitats for wildlife. NE(138).

43. Fragile communities of plants on lake shores in the high Sierra Nevada in California have deteriorated from overuse and information has been lacking on how meadows are formed and maintained. Attempts to restore such damaged sites have been largely based on intuition. Scientists recently discovered a chain of natural events and conditions necessary for establishment and survival of this important plant community. This new information will provide a sound biological basis for future management and restoration of vegetation around lake shores and in shorthair meadows. PSW(147).

44. Results from research at the Intermountain Station show why western cone flower persists and spreads under aspen stands and in openings. The success of this species is attributed to production of large numbers of seed that will germinate over a wide range of temperatures. Young and mature plants grow vigorously and are resistent to injury and removal of foliage. These data enable the resource manager to predict more accurately the response of this species to managerial alternatives. INT(136).

45. Success in establishing four species of introduced grasses on western rangelands often varies . Causes of this variation, up to now, have not been known. Researchers found that adequate water had to be available in the soil during the critical 6-day period of germination and emergence. If the soil does not dry too much, sufficient seedlings should survive for successful establishment of creasted wheatgrass, intermediate wheatgrass, Russian wildrye, and smooth brome. This information should contribute to more successful seedings on western ranges. INT(145).

46. Burning is a natural method for improving sagebrush-infested range in southeastern Idaho, but the long-term effects are not well known. The Intermountain Station reported that 30 years following a fire, sagebrush had returned to preburn densities on the study area. After 12 years, grass production began to decline, and after 30 years there was less grass on the area than before the fire. Based on these findings, range managers should plan to reburn sagebrush ranges at 10- to 12-year intervals to maintain maximum production of forage. INT(143).

47. Wildlife and livestock eat only certain plants of big sagebrush. Subspecies of big sage differ in palatability to mule deer. Scientists recently developed a technique to identify seeds of palatable and unpalatable big sagebrush plants. This technique provides resource managers with a valuable tool to select and plant only the more palatable subspecies. INT(141,142).

48. Wild shrubs growing on much of the land in Utah have not been improved through selection and breeding. There is considerable interest by land managers in the West to reseed or plant native shrubs to improve wildlife and livestock ranges. Preliminary tests indicate that western shrubs can be improved through selection and breeding as have agronomic crops and trees. INT(144,146).

49. Mesquite invades grasslands and reduces forage production throughout much of the Southwest. Scientists in Arizona found that the time required for plants to reach a density of 100 per acre varied from 100 to 250 years. Burning and bulldozing interrupt the invasion process, but do not eliminate mesquite. Control of mesquite is more urgent on areas where the rate of increase is greatest. RM(135).

50. Burning southwestern semidesert ranges to control undesirable brush is a well-established practice. Results from over 20 years of research in Arizona have been summarized. Lack of sufficient herbaceous ground fuel in most years seriously restricts opportunities for using fire in much of this semidesert area. The conclusion is that prescribed burning seldom increases production of perennial grasses on semidesert ranges, and it provides only partial control of shrubs. RM(134).

51. Differences among soils must be considered when planning forest management activities. Scientists, working in the Blue Mountains of Oregon, reported soils derived from volcanic ash offered greater management potential than soils derived from basalt. Soils from volcanic ash have more water available for plant use during dry periods than soils derived from basalt. Implications for management were that main-

tenance of topsoil was more critical in certain soils derived from basalt and that precautions are necessary when sampling soils, particularly if guides for fertilization are to be developed. PNW(137).

3. Urban wildlife

52. Seventy-five percent of the nation's population will live and work in cities by 2000 A.D. These urban residents want more experience with wildlife. Researchers at Amherst, Massachusetts, are developing a program to supply information for improving urban wildlife habitat and for using wildlife to increase the city dweller's knowledge of the natural world. NE(150).

4. People-wildlife relations

53. Federal agencies frequently seek public involvement in development plans for public lands. A study in West Virginia revealed people who hunt repeatedly in an area react differently than transients to changes in forest management. Also, local residents do not represent a majority of the repeat hunters. Therefore, surveys which determine the residence of forest users will help contribute to more effective public participation in policy formulations. NE(154).

54. Bird watching is increasing in popularity in the Southern Appalachian Mountains. Information on how to manage recreational areas in order to increase numbers of song birds has not been available. Recommendations from studies at the Southeastern Station give new guidelines for managing recreational areas for reasonably dense and diverse populations of birds. This information is also useful to bird watchers by identifying sites on National Forests that support particular species or a variety of bird life. SE(151,152).

5. Fish habitat resources

55. Over 2,000 miles of perennial streams could be affected by logging on National Forests in the Southwest. A survey of the literature on effects of timber harvesting on stream temperatures revealed that current information was inadequate to meet needs of forest managers in Arizona and New Mexico. Development of a research program to fill this void was recognized as a high-priority need. RM(156).

56. The first bibliography has been produced summarizing information on "the effects of logging on fish of the western United States and Canada." This annotated listing of 317 relevant scientific and nonscientific literature citations provides a convenient source of information to guide and coordinate management of timber and fisheries resources. A listing of research needs developed from a questionaire will point the way for future investigations. PNW(155).

6. Techniques or methods

57. Estimating forage production for livestock and wildlife on ranges is time consuming though necessary. Researchers at the Pacific Southwest and Rocky Mountain Stations have developed electronic instruments, computer simulation programs, and sampling techniques to make this job easier. Preliminary tests show that the electronic capacitance meter is useful for obtaining accurate estimates of forage production under a wide variety of range conditions. PSW(158,159,161,162,163).

58. Knowledge of animal movements is necessary to understand fully the biology of a species and to develop sound management practices. One of the major problems in tracking wild animals with radio transmitters has been the short life of batteries. Scientists in Arizona recently developed and successfully tested a solar-powered transmitter that will operate for an indefinite period. RM(164).

59. Resource managers need better ways to inventory present environmental conditions and to monitor effectively future departures from current conditions. Rocky Mountain Station researchers found that differences in density of images on color, infrared aerial photos could be used to identify shrubs and trees in the pinyon-juniper type. Differences in density were apparent for six plant communities. These differences can be used to inventory these forest range communities more accurately in the future. RM(160).

60. Information on the radiosensitivity of wild mammals is generally lacking. Laboratory studies were conducted in Wisconsin to determine the sensitivity of red-backed voles to ionizing radiation. Results from the study showed that red-backed voles were more resistant to gamma radiation than other voles. This information helps in our understanding of effects of gamma radiation in northern forest ecosystems. NC(157).

61. Utility companies spend large sums annually to fill holes in wooden utility poles excavated by woodpeckers. Scientists at the Southern Forest Experiment Station developed procedures to predict when woodpecker damage to utility poles was sufficient to require replacement of the pole. They also have developed techniques to extend the life of damaged poles by filling the cavities and wrapping poles with plastic to prevent further damage. SO(165,166,167).

7. Population dynamics

62. Wildlife managers in south Utah, uncertain of survival rates of pronghorn antelope fawns, were hampered in developing management programs. During a 5-year study, the activities of 117 fawns were monitored through radio telemetry until 4 months of age. Findings provided important insights on bobcats and other causes of mortality. This information will assist in setting objectives and practices for management of antelope in Utah. INT(168).

C. Improving Social and Amenity Values

1. Environmental amenities--landscapes and open space

63. Knowledge of quantitative and qualitative features affecting the esthetic values of landscape scenery can help in resource planning and management. In 1969 Forest Service researchers developed a quantitative model of landscape preferences. Now the model has been tried in Scotland. Results show that this predictive model works as well in Scotland as in the United States. This suggests cross-cultural similarities in factors affecting landscape preferences and strengthens the predictive validity of the model. NE(178).

64. Planning for recreation and other land-uses usually requires a geographic data base. Recording geographic data on contours and boundaries in a computer-readable form often is expensive. In some cases, using a digitizer is economically feasible. Joint U.S.-Canadian work developed a way of putting digitizers to work that has potential application in many planning jobs involving geographic data. PSW(179).

65. Land management requires procedures for monitoring changes in the scenic character of forests. A procedure was developed for predicting or monitoring visual impacts by setting up landscape control points—a network of permanently established observation sites. Then landscapes are plotted by

direct methods, by computerized mapping, and by photography. This method, field tested in the Teton National Forest, should be useful for most forested lands. PSW(176).

66. Urban parks and woodlands frequently are allowed to decline into a state of neglect, and they become target locations for highways and other kinds of development. A locational conflict was created by plans to route an interstate highway through Lynn Woods in Boston, Massachusetts. Feelings and strategies were examined and described for the various individuals and groups that participated in the negotiation process that developed from the conflict. Analyses such as these can help participants in future locational conflicts to arrive at solutions less painfully. NE(173).

67. Trees provide important amenities in residential neighborhoods including shade, wind moderation, privacy screening, homes for wildlife, and pleasing scenery. Research in Amherst, Massachusetts, shows that these amenity values are reflected in the market values of residential properties, by as much as 15 to 27 percent of the appraised land value. Results suggest the monetary values for retaining trees when wooded land is developed for homesites. NE(177).

68. Not much is known about the value of natural areas in the developmental processes of children. Observation of children in a New England town showed that they made great use of natural areas, such as woods, in their play. Such areas provide children with a variety of opportunities including a physical environment to manipulate, varied play experiences, and a location or place with which to identify. Information such as this can be used to design, plan for, or preserve environments that are of value to children. NE(174).

69. Birds are important amenities of woods, parks, open spaces, and landscaped lots in urban areas. A study extending from suburbs across a forested park and into a high density, inner-city area of Washington, D. C., showed great variation in distribution of birds. Birds in the urban area were found to be dependent on certain kinds and amounts of trees and shrubs. The quality of bird habitats and the quality of habitats for people were found to be directly related. NE(180).

70. If the preferences of the public for alternative landscapes are to be reflected in forest management, reliable techniques for measuring public preferences must be developed. One series of studies has tested the usefulness of the Theory of Signal Detection (TSD) for evaluating alternative landscapes. The experiments yielded systematic and reliable indicators of people's reactions to different forest scenes. The TSD method shows promise as a way of obtaining objective data that will help resource managers evaluate scenic beauty along with the other multiple uses and values of natural environments. RM(169,171).

71. About 50 species of birds share forest campgrounds and picnic areas with vacationers in the southern Appalachian Mountains. Densities of over four breeding pairs per acre have been recorded. Different kinds of birds live in the five different forest communities. Based on a scientific study, a brief guide has been written to help visitors identify and enjoy the birds. SE(170).

72. Forty-nine species of birds were found nesting in 30 forest recreational areas in the southern Appalachians. Variations in densities of nesting birds were related to cover provided by foliage less that 12 feet high and to the mixture of coniferous and deciduous foliage over 12 feet high. Clumping of understory shrubs is important to birds in open, parklike areas. Results of this research have been used to prepare guidelines for managers of forests and recreational opportunities. SE(175).

73. Feeding wild birds is a popular national pastime and a source of personal enjoyment and satisfaction for many thousands of families. It is estimated that $50 million a year is spent on birdseed. There is some evidence that widespread bird feeding has influenced important changes in bird populations and seasonal ranges. Studies of bird feeding in Amherst, Massachusetts, Boston, Milwaukee, Cleveland, New York City, and St. Louis have helped to document the economic costs to families and ecological effects of supplemental feeding of birds. NE(172).

74. Reports on the vegetation of the Pacific Northwest have been fragmented and scattered through a variety of sources, making it difficult for people to be aware of what is known and how such information may be applied to land management. An extensive document describes and illustrates the major vegetational units and their environmental relationships in Washington and Oregon. Forests, shrub lands, prairies, and unusual habitats such as areas of recent volcanic activity are described in detail. Land managers and all others interested in the vegetation of the Pacific Northwest will find their work facilitated by this report. PNW(357,545).

2. Environmental amenities--wilderness

75. The mosaic of vegetation in a northern Minnesota wilderness area was caused by wildfires over the past 400 years. Management of this wilderness area depends upon an understanding of fire-vegetation-animal interrelations. This research documents conditions on two areas burned 33 years earlier. The kinds of plants growing on various sites today were found to depend more on what was growing there before the fire than on differences in soils or other site characteristics. Total production of browse for animals, such as moose and deer, did not differ on the two sites. Populations of small mammals also were analyzed; deer mice and red-back voles were the most common species in all timber types. NC(189).

76. Research in natural areas requires the collection of ecological baseline data. A framework for data collection, including possible sampling schemes, has been developed for use by nonprofessionals working under supervision of professional ecologists, botanists, or foresters. This is based on many years of experience in wilderness ecology research in the Boundary Waters Canoe Area. NC(188).

77. Ecological studies in the Boundary Waters Canoe Area show that the primeval forest was fire-dependent. Even before man, periodic fires determined the composition and character of the forests and wildlife habitats. Excluding fire has created unnatural conditions. Major changes, including undesirable ones, could result. Prescribed burning and monitored lightning fires can help to maintain the ecosystems in this wilderness area. NC(184).

78. Charcoal within annually laminated sediments in lakes shows the history of fire and vegetational change over long periods of time. Lake sediment analysis was important in establishing the major role of fire in virgin forest ecosystems of northeastern Minnesota. Lake sediments for the past 1,000 years revealed that fires occurred every 60 to 70 years on the average. Intermittent charcoal deposits throughout the 10,000 year period of sedimentary records shows clearly that fire has been an important factor affecting ecosystems. NC(193).

79. Effective management of wilderness resources requires the ability to measure attitudes, preferences, and perceptions of visitors without bias. A study on survey methods examined the hazards of introducing bias due to: (1) differences in the situation between the wilderness and home where people

respond to questionnaires; and (2) differences between people who return mail questionnaires and those who do not. Results show that these two biases produce differences in degree of response but not in kind of response. The differences could be important if comparisons are made between noncommensurate samples. NC(190).

80. What beneficial psychological gains occur to an individual during a challenging experience in a natural area? This question is asked often, and opinions are abundant. However, there is almost no research to back up or refute the opinions. This study reports preliminary results of tests in Michigan involving groups of youths at the McCormick Experimental Forest. A 2-week wilderness challenge was found to force youth into active-participant roles and to demonstrate that they can face and overcome difficulties and fears. Feedback is fast and unambiguous in dealing with nature under primitive conditions. Under these conditions, youth seem to improve their awareness and thinking processes. NC(182).

81. With increasing scientific data and experience, fire is becoming better understood as a component of natural ecosystems, rather than only as an enemy of man. Time is an important factor in forest plant succession, and man's perspective is often short when compared with nature's time scale. In the Boundary Waters Canoe Area of northeastern Minnesota, five major roles of fire in influencing and controlling ecosystems have been identified. Natural areas, such as parks and wilderness, pose a special challenge in the management of fire. NC(194).

82. Research on wilderness use and management in the western United States has led to development of some useful management tools. Mandatory wilderness permits is one of these. Use of the permits helps create an opportunity for the manager to assist the wilderness visitor in trip planning. It also generates more reliable management information on wilderness use. INT(186).

83. Wilderness areas are managed for both preservation of nature and wilderness recreational use. Defining quality of experiences in wilderness has been an important and difficult problem. Visitors to four wilderness areas in Montana, Utah, Wyoming, and Minnesota were studied. Most of them preferred low intensities of use (solitude). Large parties had a strong adverse effect on quality of experience for others. Solitude was more important at campsites than on the trails. Litter was disliked even more than crowding. Limits on party size, encouragement of off-season use, and zoning were suggested actions for management. INT(191).

84. The carrying capacity concept is being adopted as an approach to management of recreation in wilderness areas. One critical element is being able to define the limits of acceptable change in wilderness ecology and experiences. Clear objectives for management also are necessary. The principal approach to wilderness management must be regulation of visitation. A multidimensional model for relating managerial objectives and alternatives to carrying capacity has been developed. INT(181).

85. Wilderness management should be based on clear objectives. Analysis of commonly proposed objectives shows that they typically are centered on man or on natural biological systems (biocentric). The biocentric approach is proposed as the better one because it is most consistent, stable, and desirable. In the long run it will better serve man's needs. PNW(185).

86. Increased hunting pressure on game populations, which often are static or declining, can only reduce hunter success. For deer and elk hunters in Montana, success (killing game) was a major necessary component of satisfaction with this recreational experience. Success in the hunt is necessary, but the kill alone does not produce high levels of satisfaction. Game management programs should provide for a variety of environments and different styles of hunting. INT(192).

87. Public attention tends to focus on the issue of classification of wilderness, while the concept of "managing" a natural, unmodified area puzzles many people. Research has helped formulate principles of management from both ecological and social points of view. The ecological aspect includes: (l) preserving the integrity of basic ecological processes; and (2) controlling visitor impacts. Social management focuses on: (l) developing the opportunity spectrum, (2) managing the wilderness periphery, (3) respecting visitors' freedom, and (4) protecting solitude. Management, according to these principles, is essential for preserving natural ecosystems and wilderness experience quality. INT(187).

88. Contiued research by the Forest Service shows that the quality of a wilderness recreation experience is affected by the numbers of people met and campsites shared. Regulation of visitation is an important way of managing wilderness areas to protect solitude and wilderness ecosytems. Many alternative approaches to managing a wilderness can be tested and evaluated with a new computerized simulation model. Developed with the help of scientists at Resources for the Future and programmers at IBM, the model is being prepared for use by managers of wilderness areas. INT(183,549,550,551,552).

3. Managing recreational opportunities

89. Many parts of the Boundary Waters Canoe Area receive heavy visitation. Campsites must be designed and located to withstand pressures of use and still serve the visiting public. Twenty- three newly developed campsites were studied over a 5-year period. Most changes in vegetation and soil happened during the first 2 years. The researchers developed criteria to enable managers to place and design campsites that will meet the needs of recreationists and minimize environmental impacts of camping. NC(211).

90. Recreational carrying capacity is a major issue in management of recreational opportunities. Researchers experienced in this kind of work have developed an annotated bibliography of over 200 citations covering both the ecological and social dimensions of carrying capacity. Two especially important functions of this bibliography are: (l) to show the breadth and richness of information available to decison makers; and (2) to portray the gaps in our knowledge as a basis for designing future research. INT(221).

91. Scientific determinations of what people seek in the out-of-doors—preferences, personal values, and motivations--will help resource managers meet the growing demand for recreational opportunities. Fishermen in Michigan were found to be motivated by four unmet needs: temporary escape, achievement, exploration, and experiencing natural settings. In another study fishermen and canoeists were found to differ in their needs for affiliation, experiencing nature, and achievement. NC(206).

92. Methods to better measure people's interactions with natural environments are being refined. Photographs taken by hikers on a natural trail at Kensington Metropolitan park in southeastern Michigan were analyzed to identify the scenes and landscape features of most interest and value. This preliminary work shows hope for quantifying aesthetic values according to people's likes and expectations. NC(196).

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93. The natural environment is a part of outdoor recreational experiences and of gardening. Studies of the satisfactions and benefits of gardening experiences help provide a basis for more difficult research on the benefits of recreational experiences. For some people a garden is a miniature piece of nature compressed in space, and gardening plays a role in people's lives similar to encounters with nature through some recreational activities. From a study made on community land donated by the University of Michigan, three kinds of benefits were identified: (l) Those based on working in the soil, seeing things grow, and being out-of-doors. (2) Those based on sustained interest or fascination, diversion from routine, opportunity to relax, sense of accomplishment, and esthetic pleasure. (3) Those based on tangible benefits, such as production and use of food. NC(204).

94. Family camping, involving over 40 million Americans, varies from backpacking to comfortable rolling homes. It is sometimes an end in itself, but often it is a means of access to other recreational activities, such as fishing. A general marketing study shows big changes in equipment used and in campgrounds during the past l5 years. More than 800,000 campsites in l5,000 campgrounds, about two-thirds commercially operated, are available. NE(210).

95. Camping and recreational vehicle travel have become major outdoor recreation markets in America. An annotated bibliography summarizes 230 published and unpublished surveys and studies between l936 and l973. Its use will lead investors and manufacturers to factual data about camping patterns. Researchers will find it to be a useful guide to available literature as well as an indicator of areas needing further research. NE(208).

96. Developers of commercial and public campgrounds and their service industries frequently need information concerning the growth pattern of their industry. Knowledge of whether the industry is expanding, stable, or contracting is vital to marketing and development strategies. Findings of a study of commercial campgrounds in New Hampshire indicate an industry which has stabilized at approximately 200 enterprises in the State. This research, indicating market saturation, is vital to potential market investors and operators considering expansion. NE(209).

97. Planning for recreational developments often fails to take a comprehensive view of trends in outdoor recreational markets. A large number of facilities are well-designed but unnecessary or poorly located. A generalized model of recreational market growth and interrelationships among sectors has been developed. NE(207).

98. Ski area managers are interested in having an effective promotional program, one that attracts skiers. Advertisements in newspapers and on radio and TV were analyzed; and 344 skiers representing eleven New York ski areas were interviewed. Existing advertising was not very effective. The more effective promotional programs were based on careful study of origin and charactistics of the skiers. NE(197).

99. Crowding, due to the growing popularity of recreational boating, can decrease the level of satisfaction of boaters and can threaten their safety. Peak use of boaters varied among 14 lakes studied in the Adirondack Forest Preserve of New York State. Most of the differences in rates of use relate to the number of boat-launching facilities per mile of lake shoreline. The number of overnight accommodations, size of lake, and miles of shoreline also had an influence. The information developed in this research can help recreational planners and managers to reduce peaks in boating use and to improve water safety. NE(198).

100. Pay-for-fishing ventures have increased without the benefit of market information; many of these businesses have failed. A study of fishermen in New York State showed they only are willing to pay to fish if a quality experience is provided. Comparing the costs of providing a quality experience with prices fishermen are willing to pay indicates that many operators may not be able to provide the experience and gain a reasonable profit. These findings should help operators to judge the economic feasibility of their enterprise before starting their venture. NE(212).

101. Recreation planners try to develop rational plans for the future. A scientifically designed study called on a panel of experts to identify key environmental events that will affect resource management. Events fell into five broad categories: population and work force; future urban environments; pollution control and policy; natural resource management; and wildland recreation management. With information on major trends in these events, resource planners, developers, and managers will be in a better position to develop effective programs for environmental management. NE(220).

102. Land-use planning is a complex, difficult job. Systems analysis techniques, used successfully in other planning, could help improve land-use planning. A study of one Forest Service Ranger District in Colorado showed the applicability of selected techniques of systems analysis in land-use planning. Results will be useful in planning for forest lands with similar resources and uses. PSW(215).

103. Techniques are needed for predicting changes in use of roads and highways as recreational developments or attractions are added. A study in the Black Hills of South Dakota produced such a prediction model. It uses data on recreational attractions, overnight accommodations, the road network, kinds of travel, and numbers of autos in the network. The model will be useful in simulating and analyzing proposed changes before they are made. PSW(199).

104. Recreational activities in resident summer camps reflect the objectives of the institutions sponsoring the camps and may significantly influence future preferences of youths for recreational activities. In Alabama and Florida, 162 camps were studied. Nearly all camps offered swimming and hiking. Scout camps stressed character development and involvement with nature. Camps sponsored by religious groups stressed spiritual development with recreation as a diversion. Private camps offered more activities, related to social status, such as horseback riding, archery, and water skiing. The analysis provided insight into how recreation is developing as a social institution and how it serves other functions. SO(213).

105. More needs to be known about the tradeoffs made when camp planners compete for inexpensive land close to the cities they serve. Site characteristics, including forests, water, soil, and elevation, were determined for 152 camps—73 in Alabama and 79 in Florida. Camps exhibited much variety in their environs, and it was difficult to specify normative conditions for their location. Good drainage and medium to coarse soil texture were common to most. Forested area within a mile of the camp also showed little variation. Building density, relief, and the proportion of land to water were more variable and best predicted by the characteristics of the region in which camps were located. Site characteristics seem to have a high degree of substitutability and no one characteristic is a criterion for site selection. SO(214).

106. Managers of natural resources, game populations, and recreational opportunities need to know more about how to provide for quality hunting experiences. People hunt for different reasons and define a satisfactory or quality experience

differently. A study of over 5,000 hunters in Washington State identified 11 different dimensions of satisfaction. These are being used to develop a scientific explanation of why people hunt and what it will take to provide a variety of hunting experiences. A related study showed that regulated plant-and-shoot pheasant areas in Washington are popular, but many users object to crowding. Implications are that such areas can be profitable, but they should be managed to distribute hunting more evenly. PNW(217,218).

107. Wildlife management is based on the concept of providing benefits to people, but interpretations are changing. In the United States there is a growing interest in appreciative, nonconsumptive enjoyment of wildlife. Hunting has become more important as a recreational activity and less important for food production. Managers of natural resources, wildlife, and recreation need to develop perspectives and objectives which best serve the public. An important part of this is recognition that hunting motives and satisfactions are complex and vary considerably among individuals. PNW(201,202).

108. The Forest Service continues to seek improvement in ways of informing the public and involving them in the decisionmaking process. A team of Forest Service social science researchers made an administrative study of the Service's experience in involving the public in planning and decisions. Many of their findings and recommendations have been included in the 1973 revised edition of "A guide to public involvement in decisionmaking," available at most Forest Service offices. The study was especially helpful in stimulating development and application of systematic methods of analyzing large volumes of unstructured public input—such as letters. PNW(203).

109. Exhibits to help people understand natural and historic resources cannot be effective unless they hold people's interest. Analysis of exhibits at four visitor centers showed visitor interest to be greatest for dynamic presentations with motion, sound, or changing lighting. Highest interest was associated with violent subject matter and interest was above average for warmblooded animals and ecological relationships. Stories that were complete or that explained cause and effect relations elicited greater interest than isolated facts. PNW(223).

110. Objectives for environmental interpretation are seldom specific enough to permit evaluation of effectiveness. A hierarchy of three or more levels of objectives is recommended, with broad goals at the highest level supplemented at lower levels by objectives that are specific and subject to measurement. If evaluation shows increased effectiveness at the most specific level, we can expect increased effectiveness at higher levels too. PNW(219).

111. Effective interpretation in parks and other outdoor settings requires understanding of the audiences to whom messages are directed. There are five important principles: (1) Visitors and leisure settings are diverse, (2) Visitors usually seek a relaxed and enjoyable atmosphere, (3) Interpretation must reward the visitor, (4) Interpretation must be understandable, (5) Effectiveness must be evaluated continually. PNW(200).

112. Many environmental interpreters have not had training in teaching methods. Successful interpretation requires use of educational principles and techniques. In preparing talks and discussions, attention should focus on: Objectives, audience characteristics, selecting and organizing subject matter, attention-holding techniques, questioning techniques, feedback, and handling of attitudes and values. PNW(195).

113. We can expect land-use conflicts and decisions to become increasingly complex. Environmental impacts of outdoor recreation are more far reaching than generally believed and include urban and social as well as rural and physical dimensions. Measuring and monitoring these impacts call for sophisticated professional skills. Public participation also is important in setting public goals and objectives for environmental standards and programs. PNW(222).

114. Accidents resulting from tree hazards can occur on most forested recreation sites. Hazard control on these sites is a matter of public responsibility. Efficient control of tree hazards requires selection of specific administrative goals and a uniform hazard-rating procedure. Then safety standards designed to meet the goals will promote a consistent level of safety at an acceptable cost. The results of this research will be useful to managers of private and public recreational sites, such as campgrounds. PSW(216).

115. Construction of a new skiing area causes disturbance of mountain soils—some on very steep slopes. Resulting erosion can be serious. Application of research results during planning and construction will hold soil disturbances and losses to a minimum. Research has shown that the following factors need to be considered: soil fertility testing; correct time of planting; proper species to plant; seed and fertilizer covering; mulching; conservation of topsoil for reuse; and use of maintenance fertilizer. The Mission Ridge ski area in Washington is a success story of effective planning and development. The same procedures can guide managers and developers elsewhere. PNW(205).

116. Thousands of people in Washington and Oregon derive considerable pleasure from outings in search of huckleberries. Unfortunately, berry fields are diminishing in size and productivity as shrubs, beargrass, and trees crowd out the fruit-bearing plants. Since most huckleberries occupy land that produces good berries but poor timber, gradual conversion of such lands to vegetation other than huckleberries is a recreational and economic loss. Several control methods—sheep grazing, burning, cutting, and borax applications--appear promising as a means of eliminating invading plant species. PNW(553).

D. Trees to Enhance the Environment

117. A wider variety of pine species is needed for planting in the shelterbelts, and windbreaks, and for Christmas tree culture in the northern Great Plains. In the search for new species, a large collection of Scotch pine from eastern Europe, Russia, and Siberia has been tested for 10 years at 3 locations in North Dakota and one in eastern Nebraska. Trees from south central Russia made the best overall performance, and these specific seed sources are recommended for northern Great Plains' plantings. RM(554).

118. The effectiveness and efficiency of many windbreaks in the Great Plains have been reduced by livestock grazing, sod encroachment, tree crowding, and old age. In a study in southeastern Nebraska some of the hardwood species were removed and eastern redcedar, ponderosa pine, and Austrian pine seedlings were planted to renovate deteriorated windbreaks. The seedlings grew best in rows farthest away from residual windbreak trees and where weeds were controlled over the entire area. Similar renovation practices can help to prolong the life and increase the effectiveness of many older windbreaks in the central Plains. RM(558).

119. Municipalities, counties, and state highway agencies in the Northeast are estimated to spend $12,000,000 per year for purchasing and planting trees. In order to design a practical

data system dealing with ornamental and shade tree planting in the region, a survey was conducted to determine who does the planting and what species are being planted. The results of this initial survey showed that relatively few species are being planted and that in each state there are key agencies responsible for the tree planting. NE(18,556).

120. Because drugs of plant origin represent an important export from West Pakistan to the United States, there has been increasing interest in the availability and proper utilization of Pakistani medicinal plants. Over 650 kinds of plants of pharmacological value were identified by a PL-480 sponsored survey in two of the major forest regions, Dir and Chitral. A further survey of the availability of selected medicinal plants indicates that it is feasible to grow or collect these plants for commercial export to the United States and elsewhere, as for example, *Datura metel* , a source of the drug scopolamine. WO:TMR(557).

E. Improving Environmental Quality Through Fire Management

1. Fire prevention, hazard reduction, and prescribed burning

121. Prescription fires create particulate problems only when their smoke exceeds the atmosphere's natural dilution capability. Four fuel and weather variables determine this capability; available fuel, its consumption rate, atmospheric stability, and the existing background particulate level. Results from this study can be used to assess the hazard of injecting an unacceptable volume of particulates into the atmosphere. SE(492).

122. Laws concerning prescribed burning differ widely among the 12 Southern States. As forestry agencies cooperate more closely with air pollution control agencies, regulations can be developed which will result in reduced smoke emission and better smoke dispersal. SE(479).

123. A guide has been developed to aid the resource manager in planning and executing a prescribed burning program in the forests of the southern United States by: explaining the reasons for burning, describing the various firing techniques, explaining the importance of weather, and emphasizing the environmental effects. SE(490).

124. Low-intensity fires can be beneficial in southern fire-climax stands, whereas wildfires of high intensity can cause severe damage. Prescribed fires enhance the environment by reducing the intensity and size of wildfires and their accompanying smoke contamination. SE(491).

125. Total biomass in a 51-year-old lowland and 55-year-old upland black spruce stand in interior Alaska was found to be 64.7 and 58.0 tons per acre, respectively. Moss layers contributed 54.6 and 45.5 tons per acre, respectively, to these totals. Availability of such data allows use of mathematical fire models to aid fuel management planning and fire danger application. INT(477).

126. Three 60-second fire prevention television spots were designed to see if a peer group member would be more effective than an enforcement authority figure (Ranger) or a symbolic figure (Smokey Bear) in reaching young adult high fire risk persons. These film spots were evaluated by two experiments. The films were more effective in the captive audience situation of the first experiment conducted with 170 northern California high school students than under normal television viewing conditions in the second experiment. In the classroom experiment all three of the films, regardless of narrator, were effective in teaching proper fire use practices. The findings suggest that fire prevention education is likely to be more effective in captive audience situations than through the use of a mass medium such as television.(478).

127. Many land managers wanted to know the effect of time in place on prevention sign awareness. Comparison of effectiveness of roadside fire prevention signs initially and after 6 years' exposure revealed no loss in impact and recall values. Subjective impressions of fire prevention personnel are not accurate measures of the effectiveness of a fire prevention sign. This research, done on the Lassen National Forest in California will be useful in designing a more effective program of public awareness of fire prevention. PSW(485).

128. An experimental fire prevention program was conducted in an operational situation in California from 1964 to 1970. Evaluation showed little change in measured levels of knowledge and attitudes among the resident population. Fire records did show a drop in fire starts in the area during the period, but analysis of these records and those of adjacent counties was not conclusive in showing this drop to be due to the experimental program. The experiment demonstrated that it is difficult to produce large-scale rapid changes in autonomous individuals. Results were most apparent from such specific actions as hazard reduction programs and direct educational efforts with school children. PSW(486).

129. A study of fire prevention techniques at the Southern Forest Experiment Station has shown personal contact programs to be most effective. Communications have four major components: a sender, a recipient, a message, and a medium. Research has shown that each component can be used to advantage by a fire prevention communicator when dealing with audiences likely to have strong negative feelings about fire exclusion. Personal contact is a much more effective medium than are the so-called mass media in changing these feelings. SO(483).

130. High school children in an area of high incendarism in the South were asked to express their opinions about woods burning and forest land ownership and management. These opinions were compared with those of the children's parents. It was discovered that the children held some of the mistaken beliefs about woods burning just as strongly as did their parents. Also, the children expressed an "anti-establishment" sentiment which was much stronger than that of their parents. It was recommended that an agency take these findings into account and compensate for them in order to gain a greater efficiency from their fire prevention programs in schoools. SO(484).

131. Forest and harvesting residues must be managed with forest resources. Management involves disposal, modification, or utilization for wood products. The costs and benefits of the several alternatives available to forest managers must be evaluated in relation to land management goals and constraints. The need for a decision-making framework for this purpose is demonstrated by problems and opportunities categorized in four areas: (1) unused wood fiber; (2) conflagrations; (3) impairment of forest resources; and (4) opposition to treatment of residues. PNW(493).

132. More than 21 million dry tons of wood and bark residue created annually by logging and manufacturing operations remain unused in California, Oregon, Washington, and Alaska. Costs of obtaining and preprocessing logging residue for energy and pulp and particleboard raw material were estimated and compared with selling values of mill residue for fuel, pulp chips, and particleboard. Energy for marginal sources seemed best suited for inplant steam and power

production by the wood industry. Raw material selling values make wood residue use for products more attractive than for electric power generation, but even these returns are seldom sufficient to meet the higher costs of delivering logging residue for such use alone. Production of higher valued products or public absorption of extra costs of utilization can make these residue management alternatives more feasible. PNW(487).

133. During 1969 the Pacific coastal states produced about 14,000 tons of logging residue. Average gross volume ranged from 4 to 57 tons per acre. The yearly increase in demand for electrical energy in California could be met by utilization of the available annual wood residue in that state. This research also presents alternative methods of wood residue utilization. PNW(488).

134. The numbers and costs of prescribed fire used for land management were determined for three Lake States. Approximately 12,150 acres were treated with prescribed fire during 1971. Costs ranged from a low of $0.24/acre for wildlife habitat burns to $21.60 for hazard reduction burns. This information can be used for planning and budgetary needs. NC(482).

135. Fire and accident prevention in the Lake States have been compared and analyzed. From the results it is suggested that fire investigators be required to recommend specific prevention action on each fire report. NC(481).

136. The man-caused fire problem in the Lake States was analyzed. Classes of people, activities, and causes responsible for forest fires on National Forests have been cross-tabulated. The data combinations indicate that greater prevention efforts might be directed towards hunters and fishermen. NC(489).

137. Pruning young ponderosa pine trees in fuel breaks in northern California increases the attacks by sequoia pitch moths which are attracted by the resin flow from pruning wounds. Subsequent resin flow arising from repeated insect activity not only degrades the appearnace of trees along roads, but it also tends to increase the fire hazard if prescribed burns are used to maintain fuel breaks. Fuel break construction practices can be improved by pruning only dead and dying limbs during winter months when adult moths are inactive. PNW(559).

2. Fire management methods and systems

138. There are both good and bad effects of forest fires; evidence indicates that it is possible to differentiate between the two. Land managers need to assess the effects of fire to determine if a fire meets their goals. A decision-logic guideline was developed for southern land managers to aid them in weighing the favorable aspects against the unfavorable ones. SE(499).

139. A dynamic fuel model for southern California brush fields has been developed and coupled with a previously developed fire model for predicting the changes to be expected in fire spread and intensity with the age of the brush and the time of the year. The mathematical models permit systematic analysis of the consequences of fuel treatment and fire control and projection of these consequences into the future. INT(511).

140. A computer program has been developed for a desktop calculator that incorporates Rothermel's fire spread model for predicting fire behavior characteristics. The program allows rapid access of the model to calculate fire spread. A manager can assess fire hazard from the model without using a large computer. INT(501).

141. An inconsistency arises in Rothermel's fire spread model when there are two or more categories. The inconsistency is resolved by replacing the weighting parameter for each category with the effective heating number developed from the characteristic surface area-to-volume ratio of each category. With this change the model is capable of accommodating mixtures of dead and live fuel such as occur in the chaparral brush fields of southern California. INT(502).

142. It is necessary to know the amount of heat required to bring the fuel ahead of a spreading fire to ignition for solution of fire spread equations. A mathematical model was developed for predicting this value based on the fuel particle size, the bulk density of the fuel array, and the moisture content. This research was required for incorporation into the general fire spread model used in the National Fire Danger Rating System. INT(503).

143. A long term effort to develop aerial capabilities to detect and map fires by remote sensing has been concluded. The performance requirements for a real-time recording airborne infrared equipment have been outlined for application. System capabilities are fully described and can now become operational for any agency with remote sensing detection requirements. INT(504,505,508).

144. Laboratory and field data relating droplet size distribution and dispersion formation of various fire retardants to their physical and chemical properties have been summarized. Upon completion, the study will provide the information which will allow tailoring of the fire retardants physical-chemical properties to various drop conditions and fire situation needs. INT(496).

145. Investigations characterizing retardant delivery have been outlined through summaries of dispersion pattern modeling, drop accuracy studies, droplet measurement investigations, and examination of parameters associated with subscale testing of retardant delivery. From this research, a mathematical model has been developed to aid fire management administrators in the development of an airtanker fleet based on the lowest total cost (damage plus operating) expected. INT(494).

146. Use of certain types of equipment during fire season is a major cause of forest fires in California. Analysis for a 10-year span for the Central California coastal area revealed that about 70 percent of these fires were caused by roadway vehicles—mainly automobiles and trucks--rather than farm or construction equipment, power tools, or stationary engines. Almost all automobiles causing fires were owner-operated, but at least 45 percent of trucks were absentee-owned. In almost three-fourths of fires from nonabsentee-owned equipment, the owner was a local resident or worker. Knowledge presented of the specific causes of equipment-use fires serves as the basis for specific recommendations for new legislation and stronger enforcement of existing regulations. PSW(497).

147. A computer model has been developed at the Riverside Fire Laboratory in California that reproduced the wind and convective column in a large stationary fire. This model can be used to simulate wildland fires and will be helpful in planning wind and temperature measurements inside prescribed fires. PSW(512).

148. The mixture of initial attack forces on a forest can be very important in maintaining a high benefit/cost ratio. A study on the Nez Perce National Forest in Idaho indicated the initial attack aircraft mix to be near optimal. These methods could be used to test the various mixes of initial attack forces on other forests. PNW(500).

149. Interregional suppression crews were established by the Forest Service to provide well-trained, strategically located crews for dispatch to large fires in western United States. Using computer simulation techniques, a study demonstrated a possible savings of more than 130,000 crew miles for the 6-year period, 1966-71, by moving the location of three crews and adding one more. PNW(513).

150. Fire effects need to be quantified to help do a better job of damage appraisal. Equations and graphs have been developed for predicting fire-caused tree mortality and the estimation of basal wound dimensions of surviving trees. The methods apply to black oak, white oak, and other species of the oak-hickory type. NC(507).

151. A fire-spread simulation program has been refined to permit incorporation of diurnal general wind and fuel moisture fluctuations, and a local wind model. A capability to restart the simulation at known fire perimeters was also added to offset the problem of error accumulation over time. Subsequent evaluation of the programs through a comparison of simulated versus actual spread of historical fires was hampered by a lack of suitable data on actual wind and fuel moisture conditions through each burning period. However, a general fit was obtained for the Romero fire, near Santa Barbara, California, utilizing available data as a basis for estimated input values. Because of the sensitivity of the spread model to wind speed inputs, it is important that improvements in wind modeling be a high priority. PSW(495).

152. A wildland fire protection policy has been developed for the Santa Monica Mountains, California, which is directed at the reduction of structural losses. It appears to offer more promise than either; (1) one which attempts to reduce fire occurrence or (2) one aimed at reducing the extent of conflagrations which do occur. The most cost-effective way to accomplish this is through improved brush clearance and roof resistance to fire. PSW(506).

153. A technique for final selection of functions and components for a fire command and control system for southern California (FIRESCOPE), based on historical fire data and consensus judgment to establish loss reduction factors, was evaluated using three basic system design alternatives. Preliminary analysis, including sensitivity studies, support the utility of the approach, with some refinements indicated to improve its objectivity. PSW(509).

154. Recent fire history in two southern California National Forests was analyzed to determine the credibility of management direction suggested by model predictions. Three alternative land management policies dealing with fire are suggested and some of the effects of each are predicted. Fire management appears to be the best alternative which includes accepting more fire on the landscape under prescribed conditions, but should lead to fewer large fires. INT(510).

155. Forestry is changing in both orientation and focus. Out of this change has come two criticisms of research. One, there is too much concern with abstract problems and; two, when a practical problem is attacked, the research and development of solutions often outlast the actual problem. If research is to help solve forestry problems of the coming decade, it must respond to the practitioner's needs, must produce applicable results in a shorter time, yet must not lose its objectivity and scientific quality. WO(19,498).

156. Fuels rapidly accumulate in southern forests and result in a critical wildfire danger. Prescribed burning can effectively control fuel accumulations, but many people object to the smoke produced by any type of burning. It must be demonstrated to concerned critics that burning operations can be improved to the extent that the resultant smoke and emissions will not be objectionable to living things. In addition to a need for further research developments in smoke management, there is a need for implementation techniques which assure public acceptance of fire use and control programs. SE(480).

3. Forest fire science

157. The management of national parks and wildernesses calls for the perpetuation of all natural forest ecosystems, including those that are fire dependent. This paper describes the vegetation patterns shaped by the fire environment of the Northern Rocky Mountains, relates fire-dependent species to ecosystem stability, and discusses the practical application of such knowledge to wilderness fire management. Presented is an approach to understanding fire, integrating this knowledge with management objectives, and applying constraints to prescribed actions so a fire-management plan can be evaluated. INT(523).

158. Studies of the ignition of fine forest fuels required knowledge of the heat transferred by radiation and convection to a sample within a test furnace. An instrumented gold sphere, blackened or polished, provided the data necessary to determine the heat flux components of the ignition furnace. These efforts are contributing to research on fuel ignition, crowning potential, and spot fire generation at the Northern Forest Fire Lab, Missoula, Montana. INT(526).

159. Fuel inventories on 55 clearouts of 10 acres and larger in the western larch/Douglas-fir type of western Montana show an acceptable accuracy in fuel assessment can be achieved through the use of planar intercept sampling using 3P subsampling. Use of fuel loading information when coupled with weather and other environmental data enhances the manager's ability to prescribe burn for specific objectives. INT(515).

160. Results from a mass fire project called Project Flambeau permit researchers for the first time to specifically define mass fire, describe its characteristics, set the boundary conditions fo fire size and energy production needed for mass fire, and to prescribe the required fuel-bed conditions for mass fires. Information gained from Project Flambeau will be useful in designing more sophisticated experimental and theoretical research into large and intense fires. PSW(519).

161. An established approximate graphical method suitable for accurate and efficient data reduction of thermogravimetric curves has found considerable utility in studying the pyrolysis behavior of solids. However, the underlying reason for the accuracy of the method remained unclear. It has now been shown that the graphical procedure can be derived analytically by a rigorous asymptotic analysis of the large activation-energy limit. The order of magnitude of the error is ascertained, and, should improved accuracy be warranted, the analysis provides a means of obtaining such an improvement. PSW(517).

162. Gel permeation chromatography (GPC) using polystyrene standards and viscometry were employed to determine molecular weight distribution and molecular weight averages of cellulose. For estimating molecular weight averages from the GPC retention volume distribution it was shown that calculations based on hydrodynamic volume rather than on extended chain length give values in good agreement with viscometric results. The best agreement between GPC and viscometric data was obtained by comparing the viscosity average molecular weight computed from GPC chromatograms using a model without the excluded volume correction. PSW(525).

163. Samples of ordinary "ash-free" cellulose papers and similar samples decrystallized by swelling in liquid ammonia were pyrolized in vacuo to a weight loss ranging from A0.1 percent to nearly 20 percent. When weight loss reached 1 percent both the ordinary and the ammonia-swelled celluloses showed a large drop in average degree of polymerization (DP). However, the ordinary cellulose shows this sharp drop long before there is any measurable weight loss; the ammonia-swelled cellulose changes DP only gradually in the early stages. Further, x-ray diffraction measurements show that the time the DP of the ammonia-swelled cellulose has dropped appreciably, the material has developed a significant crystalline pattern. These results support the suggestion that initial rupture of the cellulose molecule occurs at strain points at the crystalline-amorphous boundaries. This information gives us a better understanding of how cellulosic fuels such as wood burn and bring us closer to being able to design more effective fire retardants. PSW(516).

164. A series of computer programs have been designed to extract information from the U.S. Forest Service Individual Fire Reports and a statistical technique to fit a continuous distribution to a set of sampled data has been provided. Data summaries illustrate analysis of fire occurrence, detection, and initial attack time, and space and time relationships of multiple fires. Using this technique, data from the Individua! Fire Reports can be quickly summarized and presented to aid in planning fire organizations as well as guiding future research. PSW(524).

165. Wind temperature and humidity strongly influence fuel flammability, but the difficulty in outdoor experimentation showed the need for an environmental test chamber. A test chamber was designed which permits variation of wind, temperature, humidity and solar radiation either singly or in any combination. This unit has been used for studies at the fire laboratory at Riverside, California. PSW(514).

166. An analytical function has been derived which permits inclusion of varying heat transfer rates in calculation of temperature rises in forest fuels. The results of this research are basic in understanding ignition phenomenon and is an important consideration in fire danger rating. RM(521).

167. The National Fire Danger Rating System requires a fairly complex procedure of table lookups to determine fire danger components. Automation of this task has been achieved with the AFFIRMS network. AFFIRMS is a computer program and large data base, operating on a national time-sharing network, and provides field and administrative personnel with a system for entry and retrieval of fire weather data, fire danger components, and plain language information. AFFIRMS should drastically reduce the manpower necessary to implement the National Fire Danger Rating System, and aid in information flow laterally between agencies and vertically within each agency. RM(522).

168. Fuel information plays an integral part in the National Fire Danger Rating System. Operational use of this system requires fuel models representing broad fuel types. Fuel data were collected in Missouri to build fuel models for this region. Fuelbeds under 20- and 40-year black oak stands averaged 6.4 and 8.3 tons/acre and 4.0 and 4.2 inches in depth. Bulk density of litter averaged 0.33 and 0.49 lbs. per cubic ft. and of total forest floor 0.89 and 1.10 lbs. per cubic ft., respectively. This information will be used to test applicability of national models to local conditions. NC(520).

169. Buoyancy production rate, net flow velocity, and flame temperature were computed for pure heat source and fire-heat source burning woody fuels of moisture contents from 0 to 150 percent. Burning a pound of ovendry fuel produces about 50 pounds force of buoyancy and expands the atmosphere by about 670 cubic feet. Buoyancy production for the two sources shows that a fire may be regarded as a pure source yielding heated air rather than heated combustion products. This greatly simplifies the mathematical modeling of stationary fires. SE(227,518).

F. Improving Insect and Disease Control

1. Detection and evaluation

170. The eastern spruce budworm is the most important defoliating insect of balsam fir in the North Central and Northeastern States. In spite of extensive literature on effects of defoliation there is a lack of data on epicormic shoots produced in response to defoliation. These shoots, which are usually axillary in origin, increase with severity of defoliation. The production of epicormic shoots results in excessive limbiness and in a reduction of trunk fiber. NC(226).

171. The lack of knowledge about insects destructive to walnut seriously impedes advances in walnut production technology. Several important insects affect nut production and mar tree form or impair incremental growth. Some cultural and protection practices may at times cause conflicting results, as when fertilization to speed growth promotes feeding by sucking insects. Analysis and review of current knowledge of walnut insect problems provides a framework and direction for future research. NC(239).

172. In the past 10 years, fear of infestation by wood borers has limited the planting of green ash in windbreaks on the northern Great Plains. In an evaluation of the problem in North Dakota, the ash borer (*Podosesia fraxini*) was found in about one-half of the plantings sampled, and the carpenterworm (*Prionoxystus robiniae*) was found in 28 percent; both borers were common in the southwestern quarter of the state. The ash borer predominated in plantings less than 16 years old; the carpenterworm in plantings more than 15 years old. The borer problem should not prevent planting green ash wherever it is needed, but management practices should include insect control to provide adequate protection and development of effective wind barriers. RM(238).

173. The elm sawfly (*Cimbex americana*) sporadically causes serious defoliation of elms and willows, and outbreaks have been recorded from forested areas in several eastern states, as well as Colorado, Ontario, and Quebec. Delineation of distribution and notes on the biology and habits will enable county extension agents and people in similar positions to recommend adequate control measures for the elm sawfly. RM(242).

174. A defect in Appalachian hardwoods, variously called "flag-worm," "spot-worm," or "steamboat," is associated with burrows of the adult Columbian timber beetle, *Corthylus columbianus*. In a sawmill study in North Carolina, beetle defect was found in lumber from 29 percent of the black oak (*Quercus velutina*) trees sampled. However, less than 2 percent of the lumber was actually degraded. The economic loss due to this damage was $0.39 (13 bd. ft.) per M bd. ft. of lumber sawn. The damage impact is greatest in the butt and second positioned logs grading as ones or twos. These findings help to define the losses attributable to the wood borer complex. NE(237).

175. Planting of red pine (*Pinus resinosa*) has declined from 2 million seedlings a year to less than 300,000 because of the European pine shoot moth(*Rhyacionia buoliana*).

Research in Ohio over a 15-year period reveals that red pine can be returned to the list of tree species available for reforestation when management objectives include poles and sawtimber production. Native parasites and predators, mainly lacewing flies, were effective in controlling shoot moth damage. The long-term effect of shoot moth damage is negligible at worst and may be insignificant. NE(231).

176. Methods for evaluating and scheduling white pine weevil control have been developed and field tested but they require reliable estimates of the proportion of non-weeviled trees in the area. The use of 1/10-acre square plots to obtain these estimates was evaluated in sample plantations from Maine to Virginia. The optimum number of trees to observe per plot was estimated from the data and a table prepared giving the sample size required. Using this new procedure for estimating weevil intensity should save considerable time and effort when evaluating and scheduling treatments for white pine weevils in northeastern plantations. NE(243).

177. A useful pest management system for the gypsy moth in the northeastern United States will require an improved ability to predict trend in gypsy moth numbers from year to year. The numerical behavior of a gypsy moth population system in eastern New England between 1911 and 1931 was analyzed and described. Models developed for forecasting gypsy moth egg mass density indicate several naturally occurring processes that could terminate a massive outbreak, but they do not indicate mechanisms sufficient to change this population system from an innocuous to an outbreak phase. Models now being tested and perfected are essential to the overall prediction scheme and necessary for the development of a practical pest management system for the gypsy moth. NE(228,229).

178. The relation of lodgepole pine (*Pinus contorta*) mortality caused by the mountain pine beetle (*Dendroctonus ponderosae*) to various environmental factors is important in making insect control decisions. Control efforts might not be needed or might be deferred where risk of loss to the beetle is low. Studies in northwestern Wyoming indicated that tree mortality caused by the beetle was related inversely to elevation and ranged from less than 1 to 17 percent of the trees 4 inches d.b.h. and larger; mortality of trees 9 inches d.b.h. and larger (those most often infested) ranged from 2 percent of the stems or 0.8 percent of the basal area at the highest elevation to 36.5 percent of the stems or 36 percent of the basal area at the lowest elevation. Climate, because of its effect on the beetle's biology, was probably the single most important factor accounting for variation in mortality of lodgepole pine at the different elevations. Cool temperatures at high elevations delayed beetle development; consequently, the beetle overwintered as eggs and 1st and 2nd instars, stages that were particularly vulnerable to winter temperatures. The conclusion that severe mountain pine beetle epidemics are unlikely to occur at higher elevations will have important implications in lodgepole pine management systems. INT(224,225).

179. The western spruce budworm infests millions of acres of western forests annually. Efforts to predict population trends from egg mass surveys are not always successful. In northern Idaho the size of the egg masses was found to differ significantly on the three major host species: Douglas-fir, grand fir, and subalpine fir. Conversion tables were developed for each host species from the relationship between the length and width of the egg mass and the number of eggs contained. Use of egg numbers rather than number of egg masses should increase the reliability of surveys for predicting trends of western spruce budworm populations and the need for control action. INT(245).

180. In western Montana the western spruce budworm is causing serious damage to western larch, one of the most important conifers in the Northern Rockies. The budworm larvae feed not only on the foliage but also on current terminal and lateral shoots resulting in an annual net height reduction of about 25 percent and in forked, bushy-topped trees. Budworm-caused loss of height growth places larch at a competitive disadvantage with some of its associated species and because it is intolerant, larch can lose its dominance in the stand and eventually its potential for recovery. Thinning might ameliorate effects of budworm damage if done early enough for stands to recover from overstocking before becoming infested. The impact of the western spruce budworm on height growth and form of western larch may influence management of western larch stands. INT(236,241).

181. Population density and survival are fundamental measures used in basic and applied forest entomology. Simulation based on the mathematical characteristics of observed data on spruce budworm were used to examine bias and error. The method shows that bias should and can be taken into account and provides the theoretical basis and programing support. A new analytical procedure, which provides for better estimates of populations and their trends, will assist in insect control decisions. PSW(244).

182. Cone and seed insects severely hinder the production of genetically improved southern pines but losses to these agents have not been adequately assessed. The seedbugs *Tetyra bipunctata* and *Leptoglossus corculus* are sucking insects that reduce the yield of pine seed throughout the South by inserting their stylets into a cone and secreting enzymes into an ovule or seed. First-year ovules are destroyed and conelets are aborted; second-year cones may yield fewer seed or greater numbers of nonviable seed. Larvae of the geometrid *Nepytia semiclusaria* feed to maturity on developing first-year female strobili of loblolly (*Pinus taeda*) and shortleaf (*P. echinata*) pines in Georgia seed orchards usually causing the death of injured strobili. New knowledge of the losses to the seedbugs and geometrids will permit more accurate evaluation of insect-caused losses in seed orchards. SE(230,232).

183. Blacklight traps provide the seed orchard manager with a valuable tool for assessing populations of insects that damage pine seed and cones in the South. Blacklight and blacklight-blue light sources were the most efficient of six commercially available light sources of different wavelengths tested to determine which was the most efficient in capturing insects. The identification, relative abundance, and biologies of insect species determined by operating only one light trap during the growing season provides a basis for determining when controls are warranted and at what time they should be applied. If using large numbers of light traps in southern seed orchards depresses insect populations, use of light traps might become useful as a control component in a pest management system for seed orchards in the South. SE(247,248).

184. Fraser fir trees damaged by the balsam woolly aphid were thought to have no known easily detectable outward symptoms for about 1 year. These declining trees are now known to have a readily observable bark fungus, *Lachnellula agassizii* . The presence of the bark fungus can be used as an indicator of irreversible tree decline in damage surveys. SE(235).

185. Although the susceptibility of Fraser fir to the balsam woolly aphid is well established, little is known about the aphid's influence on fir seed production. Over 80 percent of infested trees in North Carolina produced some cones but these were small and confined to the upper third of the crown. Com-

pared with uninfested trees, cones from aphid infested trees had fewer full seeds, lower germination viability, and a higher level of infestation by *Megastigmus specularis* . Reduced cone production and lowered seed viability are important effects of balsam woolly aphid infestation with serious implications for reproduction of Fraser fir stands. SE(233,234).

186. Residential communities in areas threatened by gypsy moth attack need guidelines for deciding how much they should spend for control efforts. The dollar value of trees that would be killed by a single gypsy moth attack is based on the trees' contribution to property values. Much more expensive and selective control measures are justified for gypsy moth in residential areas than in timber producing areas. NE(240).

187. Dwarf mistletoe is a serious parasite of Douglas-fir in the Inland West, but is rare west of the Cascade Mountain divide. Seven additional sites were found infested with this mistletoe in western Oregon where stand disturbance is causing it to intensify. Additional knowledge on the distribution of Douglas-fir mistletoe is needed. Suppression of dwarf mistletoe might be necessary to avoid future impact to valuable Douglas-fir forests of the Pacific slope. PNW(370).

188. A method of classifying mycorrhizae is essential for research on ecology of mycorrhizal fungi. The characters useful in classification, the manner of assessing and describing these characters, and methods for identifying the causal symbiotic fungi are now developed in detail. This classification system suggests new possibilities for manipulating mycorrhizae in forest regeneration and disease control. PNW(374).

189. Truffle fungi are important to forestry in their role as mycorrhizal symbionts. Progress in research on truffles requires international cooperation, because specialists on taxonomy of these fungi are scarce. The Plant Protection Institute of South Africa joined with the Pacific Northwest Forest and Range Experiment Station in discovery of two new truffle species in South Africa. PNW(153).

190. *Armillaria mellea* is a serious root rot fungus that attacks a wide variety of forest plants. Its host range in Hawaii was recently extended with the finding of several new hosts. Sporophores of this fungus have not yet been found on any of the Hawaiian Islands. *Armillaria* root rot must be considered when diagnosing tree and shrub disorders in Hawaii. PSW(362).

191. Injuries are common on trees but their cause is not always obvious. Close observations on the formation of a long vertical crack in a western white pine illustrate that severe internal moisture stress can result in a stem wound which could easily be confused with a frost crack. INT(361).

192. The fungus *Lophodermium morbida* causes a serious disease of ponderosa pine plantations in southern Oregon. A morphological and cytological study of the fungus showed that development of the fruit body closely follows the classical pattern described for *Lophodermium pinastri* . Asci develop from an ascogenous hyphal system, frequently with crozier formation. Cytology is typical of ascomycetes. The haploid chromosome number is 8 or 9. The findings cast doubt on recent suggestions for taxonomic revision in needle cast organisms, and tend to support traditional taxonomic views. RM(373).

193. In recent years Scleroderris canker and red pine shoot blight, two branch diseases of pines, have become increasingly serious in the Lake States and the Northeast. To help in diagnosing these diseases, a leaflet was prepared to illustrate and describe distinguishing features. Early recognition of the cause of disease will help in prescribing proper control measures. NC(369).

194. Grand fir is an important component of mixed conifer forests in the Blue Mountains. Unfortunately, grand fir often has excessive defect caused mainly by decay. Although we don't have the technological know-how to completely overcome this problem, a recent guideline will help foresters obtain more accurate estimates of the amount of defect present in grand fir of the Blue Mountains of Oregon and Washington. Types of defect are described and illustrated and tables and equations are provided for converting cruise data into accurate defect estimates. Accurate knowledge on cull will help in setting optimum rotation ages and planning economic harvests of grand fir in the Blue Mountains. PNW(358).

195. Many fungi which decay wood residue on the forest floor are difficult to identify. A taxonomic description of all fungi in the *Pseudotomentella* has been published. A new genus of *Corticiaceae* (*Lazulinospora*) has been described from Arizona and a new species, *Pseudotomentella griseoveneta*, has been described from western North America. These findings aid in the definition of ecological roles that fungi have in reducing the amount of fuel and residue on the forest floor. FPL(359,363,364).

196. Some annual sessile fruit bodies of decay fungi that produce a brown rot type of decay have been difficult to identify. A white species of *Tyromyces* with a wide distribution in North America and which causes a brown rot of the wood of both angiosperms and gymnosperms has been identified as the original concept of *Polyporus lacteus* Fr. This information permits pathologists to make correct identification of this species of decay fungus. FPL(366).

197. Fungi that cause root rots in trees are important pathogens in both conifer and hardwood forests. A common decay fungus, *Scytinostroma galactinum* , was recognized as a pathogen in Maryland that causes a white rot and butt or collar rot in hardwoods and conifers. Cultural identification characteristics, described in this paper, will enable pathologists to make positive identification of this root pathogen. FPL(365).

198. A understanding of the processes associated with the development of decay in a living tree is lacking among the general public. Two illustrated booklets have been published to make people more aware of wounds and to give the public an accurate, general presentation of the decay process by discussing only the major portions of an extremely complex process that involves interactions among microorganisms, environmental factors, and trees. NE(371,372).

199. *Toona ciliata* var. *australis* (toon) is easily established in plantations, grows rapidly in the neotropics and offers promise as a high-quality cabinet wood. No pests or diseases have been reported to attack this exotic species until now. Stem attack by white peachscale, *Pseudaulacaspis pentagona* , is described. This pathogen reduces tree vigor and form of young seedlings and may ultimately reduce the value of toon in Puerto Rico and surrounding areas. ITF(560).

2. Biology and understanding

200. Defoliation of lodgepole pine by the needle miner *Coleotechnites*sp. in an outbreak in central Oregon varies within and between trees. Through field-caging studies and laboratory preference tests, it was found that different types of foliage vary in their degree of susceptibility to infestation. Differences seem to be related to a feeding deterrent in the foliage which is variable according to the tree, site characteristics, and location of foliage in the crown. The fact that tree growing conditions can influence tree resistance to needle miner defoliation suggests that stand management strategies can reduce the impact of needle miner infestations. PNW(299).

201. The European pine shoot moth, an introduced forest insect, is firmly established as a pest of ornamental pines in western Washington and represents a potential hazard to natural pine forests in parts of the West. Daily and seasonal emergence rhythms and premating behavior were recorded in central Oregon and compared with observations in Europe and eastern North America. Important differences were observed in the emergence patterns of the sexes as related to weather, intensity of infestation, and host species, and in the behavior of the sexes after emergence. Both sexes are more active during the daytime than recorded elsewhere, and the average male is much more active than the average female. Information on the behavior patterns of the European pine shoot moth is useful to entomologists for timing control programs or research efforts. PNW(255).

202. The European pine shoot moth represents a potential hazard to ponderosa and lodgepole pine forests in western North America. On the basis of controlled laboratory and field studies in central Oregon and analysis of weather records, localities in the western North American pine region were evaluated for susceptibility to damage by this insect. The most important physical factors were determined to be mean extreme winter low temperatures, annual snowfall, and dryness of the air coincident with the egg development period. Tree resistance varied by species, tree size, and rate of growth. New knowledge of the importance of low winter temperatures and associated environmental influences will be useful in directing shoot moth detection surveys and for evaluating other major pine-growing regions of the world for susceptibility to shoot moth damage. PNW(252,256).

203. A continuous supply of larch casebearer larvae is necessary to successfully propagate casebearer parasites under laboratory conditions. The cold treatment required for activating diapausing casebearer larvae in the laboratory was determined. The number of days until 50 percent of the larvae reactivated decreased from 28 to less than 1 between November and May. Being able to predict reactivation of hibernating casebearer larvae for use in a laboratory rearing program will facilitate laboratory culture and release programs of various species of larch casebearer parasites in the Pacific Northwest. PNW(287).

204. Periodic outbreaks of black-headed budworms have been reported in southeast Alaska and on Prince William Sound since 1917. The 1950's outbreak caused severe defoliation of mature hemlock; in some stands, one-third of their net volume was lost. The defoliation trend-ratio (acres defoliated in a given year to acres defoliated the year before) was directly related to regional temperature index. Since virgin stands have recovered from past outbreaks, widespread defoliation need not be viewed with alarm. PNW(267,300,301).

205. Diagnostic literature is inadequate for Olethreutines, an economically important subfamily of small moths, a fifth of which were originally named in the last century by B. Clemens. Appropriate Clemens specimens were discovered and designated as types, the ultimate reference specimens in matters of insect identification. New type designations, descriptions, and illustrations of several Clemens' type specimens of Olethreutines will permit their wider use in identification work for research and pest detection purposes. NC(279).

206. Much of the basis for stability in scientific nomenclature of organisms derives from the rule that the oldest name be used. The discovery of two names predating the one now in use for the strawberry leafroller may pose no nomenclatural crisis for this important insect if American populations are taxonomically identical with European ones. NC(280).

207. Green ash (*Fraxinus pennsylvanica*), a tree species widely used in protection plantings on the Great Plains, sometimes suffers severe branch killing and tree mortality. In North Dakota, the bark beetle *Leperisinus californicus* was found to breed only in living tissue, usually pruning branches, but sometimes it invades tree boles causing tree mortality. Another bark beetle, *L. criddlei*, attacks cut trees, trees girdled by rodents, and limbs or stems girdled earlier by *L. californicus*. New information on the biology and habits of ash bark beetles will assist with developing and applying control recommendations. RM(277).

208. A study of pine tip moths (*Rhyacionia* spp.) on the Great Plains required a technique for mounting and spreading large numbers of microlepidoptera. An efficient method utilizing styrofoam mounting blocks, cover glass, and acetate circles and strips was developed. The new technique for preparing microlepidoptera facilitated accumulation of a large series of pinned specimens for wing measurements and other observations for taxonomic studies of pine tip moths. RM(297).

209. The western pine tip moth (*Rhyacionia bushnelli*) is a serious pest of ponderosa pine on the Central and Southern Great Plains. It is a serious threat to the establishment of ponderosa pine in windbreaks. Collections of pine tip moth larvae and pupae from various locations in Kansas, Nebraska, South Dakota, North Dakota, and Montana yielded 24 species of parasitoids in seven families of Hymenoptera and one family of Diptera. New host-locality records for several parasitoids add to our knowledge of the ecology of the western pine tip moth. RM(276).

210. The western spruce budworm *Choristoneura occidentalis* is host to many species of parasitoids but the complex differs with time and place. In intensive studies in Colorado in the mid-1960's, eight species of primary parasitoids were collected in addition to all 20 species collected in earlier studies in the 1940's. Researchers and others studying the ecology of the western spruce budworm in different parts of its range will note the expanded inventory of parasitoids of the pest in the Central Rocky Mountains. RM(275).

211. The pinyon pitch nodule moth (*Petrova arizonensis*) seriously reduces growth and impairs the form of pinyon, a tree species of increasing importance in certain Colorado locations under development. The insect has a 1-year life cycle, overwintering as larvae inside the pitch nodule and pupating in the spring in the nodules. The moths emerge in midsummer and lay eggs on new shoots. The larvae feed first on needle tissue, then form the pitch nodule on the new shoot. New biological data on the pinyon pitch nodule moth will assist with development of effective, ecologically sound direct control methods. RM(251).

212. Simple and inexpensive pit traps used in ecological studies are not readily available. A new trap was made from a commonly used bark-beetle emergence cage, a major component is a large funnel onto which is affixed a jar containing a small amount of ethyl alcohol. The improved design is highly efficient in collecting terrestrial insects and other small animals. RM(288).

213. A population of *Coleotechnites* needle miners *Lepidoptera: Gelechiidae*) caused noticeable defoliation to ponderosa pines in the Boulder, Colorado area in 1971 and 1972. Although not assignable to it, this population exhibits life history and habits similar to those reported for *C. pinella* Busck, namely, a 1-year life cycle and varied infestation rates between individual trees. Other than being detrimental to host trees' appearance, this needle miner appears not to cause much damage. This information will be helpful in diagnosis of damage symptoms when future outbreaks arise. RM(295).

214. The lodgepole terminal weevil *Pissodes terminalis* is a potential pest of lodgepole pine regeneration in Colorado and Wyoming. During the course of investigations on *P. terminalis*, a small bark beetle associate, *Pityophthorus opimus*,was commonly encountered. Nothing was previously known about the ecology of *P. opimus*. Its relationship with *Pissodes terminalis* as well as elements of its life history were described. Knowledge of the relationships between the lodgepole tip weevil and its associate is important to understanding the ecology of both species. RM(274,296).

215. Without a way to confine emerging moths under natural conditions, it is difficult to know when pine tip moth emergence begins in the spring. An inexpensive cage was designed and used successfully to determine adult emergence periods of the southwestern pine tip moth, *Rhyacionia neomexicana* . The cage can also be used in research applications, as well as in timing control work, with other soil-pupating tip moths. RM(269).

216. It is often helpful to be able to predict sex of individual insects prior to adult emergence. This is especially important in some work with sex attractants. In the southwestern pine tip moth, the relative position of the genital openings, the ventral abdominal coloration pattern, and relative antennal length are all useful in determining pupal sex. This information will facilitate further field and laboratory studies of this destructive species, especially work with sex attractants. RM(270).

217. Entomologists frequently find it necessary to count very small objects, such as insect eggs, with a binocular dissecting microscope. To overcome the problem of eye fatique, which can influence accuracy, a microvideo system was adopted to observe egg masses of the elm spanworm. In addition to the magnification features of a microscope, the large viewing screen reduces eye fatigue and permits two or more persons to view the subject simultaneously. The image may also be recorded on video tape or a photograph can be made of the image on the monitor. Use of the microvideo system to expedite insect counts has numerous research and pest evaluation applications.(298).

218. Literature concerning parasites and invertebrate predators of the gypsy moth has been accumulating for approximately 70 years, much of it in numerous publications of limited circulation, which suggests the need for a published bibliography. A concise and readily accessible list of selected references is now available. The information sources on specific parasites and invertabrate predators of the gypsy moth will be useful to researchers, biological control specialists, and pest management specialists. NE(266).

219. The importance of gypsy moth larval dispersal in the spread of this pest has been long recognized but little was known about how the larvae respond to external environmental stimuli. It was learned from experiments in Connecticut that the diel periodicity of both hatching and dispersal from the egg mass and photopositive behavior together assure that larvae are in optimal position for dispersal when air turbulence is maximal at midday. The rate of larval activity depends upon ambient temperature and relative humidity. The larvae continually trailed silk and did not feed upon reaching the foliage. With the bilogical meteorological parameters now available, mathematical models can be developed and tested to predict the dispersal of larvae and define the role of dispersal in the population dynamics of this insect. New knowledge of the dispersal process adds another essential element to the development of a pest management system for the gypsy moth. NE(278).

220. In order to evaluate the effectiveness of a vertabrate predator (such as the whitefooted mice), against an insect (such as the gypsy moth), one must identify and quantify the mortality causing agents for the predator population. A radio telemetry system was designed to detect the death of small mammals and facilitate recovery of the remains. The intraperitoneally implanted radio transmitter is triggered by the drop in body temperature that occurs when the animal dies. The radio telemetry system designed, tested, and operational for studies of *Peromyscus* will be even more useful in wildlife population dynamics studies. NE(282).

221. The present method for rearing the white pine weevil (*Pissodes strobi*) in the laboratory depends on the availability of the natural food, white pine. A rearing technique and a semiartificial medium containing pine bark for rearing the insect from egg through adult was developed. Survival, fecundity, and adult size were satisfactory. Use of the synthetic medium for the white pine weevil facilitates a more efficient rearing procedure and provides a standard supply of insects for experimentation. NE(303).

222. An understanding of mountain pine beetle population dynamics is essential to developing a management system for lodgepole pine in the Intermountain Region. Crowding within beetle populations influenced both food and habitat and affected both fecundity and mortality rates. In the laboratory, survival of first-stage larvae increased as crowding increased, but rate of survival decreased as either crowding level increased or duration of crowding lengthened. Crowding shortened third and fourth larval stadia and more females and fewer males survived; in turn, the reproductive capacity of the female decreased as larval crowding increased. The measured effects of crowding on mountain pine beetle populations provide valuable parameters as inputs to population models with which to develop a pest management system for lodgepole pine stands. INT(254).

223. The behavior of the female mountain pine beetle in the flight and attack process determines the density and subsequent development of the brood in the host tree, lodgepole pine. In a study conducted in northern Utah and southern Idaho, temperature appeared to be the most important influencing factor governing onset, daily time and length of emergence and flight, and the location of initial attack. The optimum temperature range for adult beetle activity extended from about 19oC to about 32oC. Even though the sex ratio of attacking beetles favored the female, all females were mated within at least 10 days of a mass attack on the host; mated females constructed galleries at a greater rate than unmated females. The knowledge of the environmental parameters and their effects on beetle flight and attack behavior provides key information for modeling the dynamics of mountain pine beetle populations. INT(285).

224. The western spruce budworm outbreak, which began in the Northern Rockies in the early 1950's, continues unabated and annually covers about 4 million acres of forest land. Unseasonably low temperatures, as low as -6oC in western Montana in mid-June 1969, reduced budworm populations on Douglas-fir, western larch, and ponderosa pine over 90 percent and reduced budworm damage in young western larch by 54-71 percent. The occurence of an unusual physical phenomenon such as unusually low temperatures and its effect on insect populations and subsequent host tree damage can have an important influence on pest management decisions. INT(262).

225. Reproduction of the highly destructive southern pine beetle may be affected by fungi in the repository (mycangium) of the adult female. Female beetles which had their mycangial fungi destroyed by antimicrobial treatment produced substan-

tially fewer progeny from pine bolts by 13 to 124 days. Possible manipulation of the mycangial fungi offers a means for biologically controlling beetle populations. SO(249).

226. Taxonomic delineation of fungi is necessary to develop full understanding of relationships between the southern pine beetle and its microbial associates. One of these fungi, provisionally designated as SJB 133, was observed to assume one form in the fungus repository (mycangium) of the adult female but another form in the larval galleries within trees. Virulence and serological studies made on cultures of the fungus established that SJB 133 is a variety of *Ceratocystis minor* Biological control measures may be devised to disrupt the association between the beetle and its symbiotic fungi. SO(250).

227. Trees of low or declining vigor have been implicated as focal points for maintaining endemic populations of the southern pine beetle. Gas chromatographic analyses of oleoresin from 60 declining and 77 apparently healthy loblolly pine trees from southwestern Louisiana revealed no differences in monoterpene and resin acid composition. Increased bark beetle susceptibility of declining pines is evidently determined by host and environmental factors other than varied oleoresin composition. SO(268).

228. Prematurely declining pines probably provide niches for the maintenance of southern pine beetle populations during endemic periods. Trees on 5 of 100 randomly selected 0.1-acre plots in southwest Louisiana were attacked by the southern pine beetle; trees on 33 plots were attacked by the black turpentine beetle. Within a 5-chain radius of plot centers there were 46 plots with at least one southern pine beetle-infested tree, and a total of 74 infestations. Declining pines and turpentine beetle-attacked trees probably contribute to the maintenance of endemic southern pine beetle populations. SO(273).

229. The fir engraver beetle, interacting with defoliators and root rots, is the pest complex most seriously affecting management of the increasingly valuable true fir stands in the western United States. Frequencies of old fir engraver attack scars embedded in annual rings of living and dead white fir were related to: (1) increases in the volume of white fir sawtimber killed by beetles, (2) logging within the stands, (3) periods of drought and subnormal fir growth. Scars are a valuable tool in fir engraver research on host resistance PSW(263).

230. Silvicultural practices to reduce losses of true fir caused by the fir engraver require ability to identify trees and stands particularly vulnerable to the beetles. Based on a large sample of white fir growing in virgin and cutover stands, mean densities of old attack scars were higher in fir of low vigor (suppressed crown class, low growth rate) growing on poor sites (Sites II - III), which had been heavily logged in the past. Densities of embedded scars were higher in fir recently killed by fir engraver than in living fir. Scar densities offer a rapid means of assessing past tree and stand vulnerability to fir engraver, enabling rapid development of systems for risk-rating individual fir and hazard-rating fir stands. Such systems will give better direction to fir management PSW(264).

231. The lodgepole needle miner causes extensive defoliation and tree mortality, but the fundamental ecological changes are poorly known and understood. New and extensive defoliation was found in parts of Yosemite National Park. Defoliated and dead forests provide excellent opportunities to observe ecological processes in the absence of insect control, timber salvage, and reforestation. Study of the events following tree defoliation and mortality will increase our understanding of site dynamics and ability to predict the consequences of lodgepole needle miner outbreaks. PSW(272).

232. The Columbian timber beetle degrades several commercial hardwood species in the South but information was inadequate for developing detection and evaluation surveys and for the efficient application of control procedures. Observations in a red maple stand in the northeast Georgia Piedmont suggest that most, if not all, the trees within the stand are suitable hosts but whether a tree is heavily infested in any given year depends on its proximity to infested trees and the brood success of any beetles which happen to make initial galleries. The new information concerning the population distribution of the Columbian timber beetle within the tree and stand over time will be useful in location of infested trees, the definition and placement of representative population samples, and the placement of insecticides. SE(283,302).

233. An artificial diet for rearing large numbers of *Dioryctria* spp. moths in the laboratory would accelerate development of noninsecticidal control methods. A meridic medium was developed that was suitable for rearing *D abietella*, and certain aspects of the insect's nutrition were disclosed. The improved artificial medium now available will be used during final stages of laboratory bioassays and field tests of attractants. SE(259).

234. Before sex pheromones can be used effectively in integrated control systems for the cone-destroying moth *Dioryctria abietella* in slash pine seed orchards, basic information is needed on the effects of photoperiod and other factors that influence the timing of its nocturnal mating behavior. Sex pheromone release by the female moth was found to follow a predictable circadian rhythm that was entrained to imposed photoperiods. Mating behavior was strongly influenced by photoperiod and male moths were found to be responsive to the pheromone for a period about twice as long as the period of female pheromone release. New information on the behavior of this moth will be useful in timing control methods and in detection surveys using the insect's sex pheromone. SE(260,281).

235. Fall cankerworm eggs parasitized by *Telenomus alsophilae* were found no earlier than mid-March in northern Virginia although elsewhere the important parasite attacks 4-5 months earlier. In northern Virginia the host doesn't lay its eggs until colder periods of the winter when the parasite is inactive. Therefore, population sampling in this area has to recognize this local anomaly to prevent misleading egg mortality data.. SE(261).

236. A defined diet is necessary to determine the dietary and host selection requirements of the pales weevil, *Hylobius pales*, which is the most serious insect pest of pine reproduction in the eastern United States. Linoleic, linolenic and palmitic acids, tocopherol, and p-sitosterol satisfactorily replaced wheat germ, wheat germ oil, and loblolly pine phloem in a previously described diet. The defined diet will permit researchers to determine the essential host constituents and their influence on the development and behavior of the pales weevil. SE(253,257).

237. Natural sources of attractant chemicals must be recognized before synthetic insect attractants can be identified. The frass of virgin female *Scolytus multistriatus* evokes an excitant-turning reaction from walking male beetles in laboratory studies. This frass from virgin female smaller European elm bark beetles has been identified as a good source of stimulatory chemicals that might be used in Dutch elm disease control programs designed to identify and synthesize a useful pheromone. NE(284).

238. To control the oak wilt disease, spread of the wilt fungus from diseased to healthy trees by nitudulids and oak bark beetles must be prevented. In an experimental study, felling or girdling diseased trees greatly reduced the number of fungus mats, the source of inoculum for nitidulids, but neither treatment prevented bark beetle breeding nor reduced disease incidence. Felling or girdling diseased trees is not considered an effective control measure for the oak wilt disease. NE(286).

239. Larvae of the carpenterworm tunnel in the trunks of oaks and other living hardwood trees and degrade their potential lumber value. Research studies are contributing to a more complete knowledge of the biology of this serious pest. The number of carpenterworm larval instars is influenced by sex, heredity, and temperature. Head capsule widths for both sexes are about equal during the early instars but female head widths later become significantly larger. Early instars can be satisfactorily identified by head widths. Growth in the carpenterworm does not fit Dyar's rule of geometrical progression, but rather increases at a decreasing rate through instar 7 then levels off near a growth ratio of 1.00. This information is of immediate value to insect morphologists. SO(289).

240. The hickory borer, *Goes pulcher* , is among the more important insects of hickory and pecan throughout eastern United States. The trunks of young trees are damaged by tunnels that extend horizontally or upward obliquely for 2-5 cm, vertically for 6-12 cm, then horizontally back to the surface. Open-grown trees and those growing near openings within young stands are most heavily attacked. Resulting damage includes breakage of weakened stems, wood degrade, and predisposition to stain and decay fungi. Natural mortality of the insect is caused by heavy sap-ooze and woodpecker predation. Control now consists only of removing brood trees. An understanding of the biology of this insect will lead to better prescriptions for its control. SO(290).

241. The carpenterworm is the most serious borer in southern hardwoods and knowledge about its sexual behavior and life cycle is needed to develop controls. Experimentation shows that female carpenterworm moths call with a sex attractant at a mean age of only 29 minutes and mate only once at a mean age of 59 minutes. The response of polygamous male moths peaks in midafternoon and ceases at nightfall even when females continue to call. Fertile females deposit their eggs in deep crevices of the bark of host trees for a period of several days after mating. Moths with 2-year life cycles are generally more productive than 1-year moths and those reared from oaks are usually more prolific than those reared from American elm or green ash. Mean numbers of eggs deposited range from 331 for 1-year moths reared from American elm to 737 for 2-year moths reared from Nuttall oak. Knowledge of the life cycle of the carpenterworm will be used to predict epidemic behavior and provides clues to where artifical attractants might be useful in sampling and control efforts. SO(293,294).

242. Sex attractants of some agricultural pests have been known for many years, but only recently have they been recognized in forest pests. Two virgin female moths of the pinkstriped oakworm, *Anisota virginiensis*,placed in screen traps attracted a total of 209 males over a 3-day period. Attraction began daily around 10:00 am and continued for approximately 1-1/2 hours. The potent sex pheromone of virgin female oakworm moths appears useful for studying, surveying, and controlling this hardwood defoliator. SO(291).

243. Stands of Molica pine (*Pinus peuce*) in Yugoslavia are being studied in a PL-480 project to determine the identity and significance of insects and diseases. *Fomes* (*Phellinus*) *pini* was recorded for the first time in the crowns of old trees. The presence of *Fomes* (*Phellinus*) *pini* in Yugoslavia is important and of interest because it is destructive in the United States as well. WO-FIDR(387).

244. Introduction of alder to a site effects concommitant introduction of alder's obligate mycorrhizal fungi. *Lactarius obscuratus* has been confirmed as one symbiotic fungus commonly associated with red alder. If such fungi prove antagonistic to conifer root pathogens such as *Poria weirii* , they can provide biological control of *weirii* where alder can be established. PNW(385).

245. Endomycorrhizal fungi are known to absorb mineral nutrients from soil and translocate them to host plants. Transfer of host photosynthates to the mycorrhizal fungus has now been experimentally demonstrated by radiotracer methods. In fact, spores formed by the fungus accumulated tagged carbon from the host at concentrations 20 times those of the host roots themselves. The mutual benefit of endomycorrhizal symbiosis to both host and fungus is firmly established. PNW(392).

246. *Poria weirii* , the most destructive root pathogen of conifers in the Pacific Northwest, envelops its colonies in dense tissue called "zone lines." Zone lines protect *Poria* from antagonistic organisms and hence extend the infection potential of the pathogen. Site treatments which break through zone lines of *Poria* colonies in buried wood and encourage invasion of the colonies by microbial antagonists offer good potential for control of this disease. PNW(409).

247. The weed, senna seymeria, was recently discovered as a parasite on the roots of southern pines. A survey indicates that the parasite is most abundant in sandy pine flatwoods of the lower Gulf and Atlantic Coastal Plains from southeastern Louisiana to southeastern Virginia. It occurs less commonly on dry, rocky soils of the upper Coastal Plain, southern Piedmont, and southern Appalachian Ridge. Parasitism was found in pine plantations only in Georgia. These findings indicate that senna seymeria is not a widespread problem. SO(118).

248. Pathogenicity of disease-causing organisms depends on the pathogen's capability to neutralize host defenses. Growth of the root-rot fungus *Poria weirii* is inhibited by relatively high concentrations of phenylacetic acid, a phenolic substance. At lower concentrations, however, the fungus metabolizes the substance to a noninhibitory compound. Probably, defense effectiveness of many naturally-occurring inhibitors in host tissue is similarly related to concentration. PNW(402).

249. Root rotting fungi such as *Poria weirii* generally have several physiological strains, but little is known about the significance of strain differentiation to disease occurrence in forests. In laboratory experiments, a combination of phenolic compounds that occurs in roots of the *Poria* -resistant red alder inhibited growth of two isolates of the fungus. The combination occurring in roots of the *Poria* -susceptible Douglas-fir stimulated growth of one isolate but inhibited the second. The two isolates responded in opposite ways to some of the compounds administered individually or in various other combinations. Phenolic compounds appear to be part of roots' defense mechanism against *Poria* invasion. However, since strains of the pathogen vary in reaction to phenolics, effective resistance might be difficult to attain. PNW(429).

250. Knowledge about insects as vectors of mycorrhizal and pathogenic fungi is scattered in numerous publications. To develop a better understanding of this ecological role of insects, a preliminary bibliography on insect mycophagy is being prepared for IBP's Coniferous Forest Biome. This will aid researchers of many disciplines to develop a fuller understanding of forest ecology. PNW(383,384).

251. Root growth and decomposition are vital processes in soils but are little understood quantitatively or qualitatively. Studies of fungi, roots, and rotten wood in an old-growth Douglas-fir western hemlock stand in Oregon revealed that over 22% of the ground surface was covered with rotten wood. On a hectare basis, soil in the stand was estimated to contain about 35 metric tons (MT) dry weight of roots larger than 5 mm in diameter, 8 MT of roots 0.5-5 mm diameter, 5 MT of ectomycorrhizae, and 6 MT of fungal hyphae and sclerotia. In the course of a year, more than 55,000 fungal sporocarps were produced per hectare. Clearly, belowground life comprises a significant portion of the biological activity of the forest. PNW(382,428).

252. The European mistletoe *Viscum album* is established in an area of about 20 square miles in the vicinity of Sebastopol, north of San Francisco. The mistletoe is known on about 25 tree species in California including several native trees. Because this mistletoe has an extremely wide host range (in Europe essentially all deciduous trees are susceptible) and is often quite damaging, it could become a serious pest along the entire Pacific Coast. The California Department of Agriculture, in cooperation with the U.S. Forest Service, is evaluating the Sebastopol infestation, to determine whether an eradication program is warranted. PSW(406).

253. The scale insects *Hemiberlesia rapax* and *Aspidiotus nerii* were found on the Honduran dwarf mistletoe, *Arceuthobium hondurense* . The fungus, *Nectria flammea* , parasitizes these scale insects. The overall effects of the scale and the fungus on dwarf mistletoe populations are unknown. However, this mistletoe is extremely rare and these insects may, in part, be responsible. RM(391).

254. To the present, few plant rusts have been grown in pure culture on synthetic media. Colonies of *Cronartium ribicola*, initiated from bits of infected tissue cultures, have been maintained up to 18 months by sequential transfer (30 days) on a synthetic medium. Culture homogenates of several spore producing isolates infected *Ribes nigrum* leaves and resulted in uredia and telia of *C. ribicola*. Chances of culturing other pine stem rusts would appear to be considerably enhanced by success here. This is a means of studying physiological needs of these fungi exclusive of their hosts. INT(389).

255. Fruiting structures of parasitic fungi are sometimes found in unusual sites on the host. Urediniospores of *Cronartium ribicola* within the petiole of *Ribes petiolare* occurred internal to xylem tissues within the region of undifferentiated parenchyma cells (pith). Fungal tissues were sparse; and fully differentiated sori were absent, in contrast to uredia found in the lower leaf surfaces. No biological advantage to the fungus is attached to its fruiting within the petioles of Ribes leaves. INT(388).

256. The physical association between *Cronartium ribicola* and host cells of *Pinus monticola*, western white pine, has not been fully clarified. With scanning electron microscopy (SEM) it was found that the sheathing material of mycelium seems to cement the myselium to host cell walls, but there is no evidence of lysis of the latter at contiguous points. SEM, while providing some insight to this physical relation, promises to be a useful tool in further extending knowledge of this host-parasite complex. INT(430).

257. Blister rust cankers, caused by *Cronartium ribicola* on white pines, are frequently inactivated to varying degrees by other fungi (such as *Tuberculina maxima*). Although their mode of action has been a matter of conjecture, such knowledge could be prerequisite to enhancing their biological control potential. *T. maxima* destroys only host tissues infected by the rust fungus and causes death and autolysis of the rust. There is no evidence that *T. maxima* is parasitic on the rust *per se* , and its mode of action is directed at the rust-infected pine tissue. Since *T. maxima* works on rust infected tissues, its variable effectiveness as a control agent is now understandable and appears not to be easily manipulated by man. INT(431).

258. Pole blight disease has been a serious problem to management of naturally regenerated stands of western white pine. Now the disease has been found in a plantation established in northern Idaho less than 40 years ago. This emphasizes the need to classify sites as to their pole blight hazard before replanting to western white pine. Classification is fairly easy and is based on soil and moisture availability characteristics. Because sites might now be regenerated with costly stock resistant to blister rust, land managers are advised to restrict their planting to low risk pole blight sites or to accept a high probability of damage and loss from pole blight. INT(401).

259. *Atropellis* cankers are found on several species of pines in North America. To aid in recognizing these fungal diseases and to reduce their impact, a bulletin about *Atropellis* canker disease was published in the Forest Pest Leaflet series. *Atropellis* cankers cause severe defect through stem distortion and an accompanying conspicuous blue-black stain in infected wood. Control is often feasible by lowering the source of inoculum through removal of infected trees during silvicultural operations. RM(403).

260. *Dothistroma pini* needle blight causes extensive damage in young plantings of Austrian, ponderosa, and other pines in the Midwest. Infection studies in eastern Nebraska revealed that first-year needles of Austrian and ponderosa pines were resistant to infection until mid-July. Infection of previous season's needles occurred as early as late May and continued into September. Rainfall during the period June-September is a good indicator of amount of infection to be expected. First symptoms were observed as early as 7 September. The results provide a sound basis for determining when protective fungicides (Bordeaux mixture) should be applied. RM(410).

261. Several diseases reduce the esthetic value of pines and junipers in Midwest landscapes. A review was made of recent research on the biology and control of six of these diseases; Dothistroma needle blight, brown spot needle blight, Diplodia tip blight, and Lophodermium needle cast of pines, and Phomopsis and Cercospora blights of junipers. This information is being used by foresters and horticulturists to protect desirable trees in the Midwest and the Great Plains. RM(411).

262. Many plant-parasitic nematode species are associated with rootlets of forest trees, but damage to ectomycorrhizae by these species is generally overlooked. Microscopic examination of ectomycorrhizae from mature *P. ponderosa* from southwestern New Mexico showed that second stage root-knot larvae readily penetrated fungal and root tissues. Development of sedentary females resulted in rupture of fungal mantles, and compression and collapse of cortical cells, Hartig nets, and xylem tracheids. Results indicate that these nematodes may alter the role of ectomycorrhizae as biological deterrents to pathogenic root infections. RM(413).

263. Although the genus *Pinus* has been the subject of extensive mycorrhizal studies, there are only six pure culture confirmed mycorrhizal symbionts of *P. ponderosa*. When seedlings were inoculated with pure cultures of 15 fungal species from central New Mexico, mycorrhizae were synthesized

during a 5-month period with *Suillus granulatus*, *Amanita muscaria*, *A. pantherina*, and *Lactarius deliciosus* . The detailed morphological anatomical descriptions of the synthesized mycorrhizae may be useful in developing a natural mycorrhizal classification. RM(414).

264. *Armillaria mellea* can be killed in culture by mycophagous nematodes, but it is not known if these nematodes can suppress root rot development on seedlings and reduce seedling mortality. In flask cultures with *A. mellea* , 5 of 12 *P. ponderosa* seedlings died during an 11-week period. When *A. mellea* and *Aphelenchoides cibolensis* or *Aphelenchoides composticola* were combined, only 1 of 24 seedlings died. The results provide information that may aid in evaluating the role of mycophagous nematodes in the development of root diseases. RM(415).

265. Hypoxylon canker is a serious cause of mortality of aspen in the Lake States, and despite years of research, its etiology remains unclear. A phytotoxin obtained from cultures of *Hypoxylon mammatum* and from diseased tissue of aspen cankers has been found to cause the bark to collapse, a symptom of this disease. Bioassays show that leaves of poplar species resistant to Hypoxylon canker are also resistant to the toxin. The discovery of this toxin may be significant in resolving the still unknown means by which Hypoxylon infects aspen trees. NC(418).

266. The Polyporaceae is one of the largest groups of forest fungi in the world and its members are the principal organisms involved in biodegradation of wood. Some of these fungi cause enormous economic losses as pathogenic root rotters, destroyers of wood in living trees, and decayers of wood in service. Others fulfill an extremely beneficial role by decomposing dead branches, stems, and other unwanted wood residues, thereby releasing nutrients for additional productive forest growth. Researchers in the PL-480 cooperative research program recently described the host materials, ecological niches, and general distributions of the many Polypores in West Pakistan. This new information will help the developing countries of Asia to intensify productive forestry by providing criteria for selection of tree species and sites that minimize losses to root rot and decay fungi. WO-PL-480(412).

267. Laboratory research on dwarf mistletoes has been hindered by lack of a quick and effective technique for making artificial inoculations. This has been remedied by storing seeds at 2oC and 75 percent relative humidity, germinating them in 2 percent hydrogen peroxide, and gluing the young plants with poly-vinyl acetate to greenhouse trees. This technique is useful for a wide variety of mistletoe species and often leads to emergence of aerial shoots within a few months. This will greatly increase the capacity for productive research on control of mistletoes by chemical, biological, and genetic means. PNW(397).

268. An interaction of microorganisms is involved in biodeterioration of wood in standing trees. It was experimentally proved that even "clean or healthy" wood of aspen has an indigenous bacterial population. These possibly could provide an important source of nitrogen necessary for biodeterioration by decay fungi. Consequently, these seemingly innocuous bacteria might be important components in cycling of nutrients in aspen ecosystems and their biology might be regulated to reduce the occurrence of harmful wetwood and tree decay. PNW(398).

269. Sawtooth oak (*Quercus acutissima*), which has been proposed for wildlife plantings in southeastern United States, is a potential alternate host of the fusiform rust that attacks southern pines. Greenhouse experiments showed that sawtooth oak seedlings were susceptible to *Cronartium fusiforme*, and that the telial columns produced viable basidiospores. This suggests that sawtooth oak could contribute to increased rust incidence, and therefore should not be planted near susceptible pines. SE(379,380,381).

270. Loss of timber volume and quality through heartwood decay is a serious problem in the management of the almost 3 million acres of oak forests in Ohio. Nine species of decay fungi account for over 80 percent of the identified infections in oaks. One out of every 4 decay infections and 65 percent of the total decay volume in oak were associated with fire scars. The percentage of decay in oak stands 30 to 90 years old was about 1.5 percent compared to 5.0 percent for stands over 90 years old. Information gained about the association between fire-caused injuries and subsequent decay suggests that good fire protection and shorter rotations should be considered in the management of oak forests in Ohio. NE(375,377).

271. During the past few years there has been a marked interest in planting black walnut for timber as well as nut production. In recognition of this interest, information about the important diseases of walnut and their control measures has been made available for walnut growers in a summary publication. NE(376).

272. Definition of the conditions necessary for the establishment of *Fusarium* canker of forest trees is needed to develop effective controls. The change in the carbohydrate content of yellow-poplar seedlings following defoliation was investigated but no change was found that could be correlated with defoliation. Likewise, no correlation between defoliation and canker establishment was detected. The failure of defoliation to contribute to canker establishment suggests that isolated insect defoliators of yellow-poplars in plantations would not weaken the trees sufficiently to induce a proliferation of *Fusarium* cankers. NE(396).

273. More information is needed about the physiological interactions between canker fungi and host trees before effective controls can be developed. Research studies of *Fusarium* canker on yellow-poplar seedlings have shown that infection is associated with greater rates of photosynthetic assimilation by the seedlings and that *Fusarium* cankers do not interfere with translocation of photosynthate. The finding that *Fusarium* cankers do not alter the flow of photosynthate provides direction for future research seeking a control procedure. NE(395).

274. The biological cause of diseases that produce growth abnormalities referred to as witches'-brooms in walnut is unknown. An electron microscope investigation of the phloem tissues of Japanese walnut revealed the presence of a mycoplasmalike organism in diseased but not in healthy leaf, stem, and root phloem cells. This discovery, that the cause of witches'-brooms in walnut may be due to mycoplasmalike organisms and not to a virus, provides specific direction for development of control procedures for witches'-broom diseases. NE(419).

275. Little is known about spread of the disease, elm phloem necrosis. One hundred insects that either are found on or probably feed on elm have been recognized as potential vectors of elm phloem necrosis. This evaluation of potentially important insects outlines the boundaries for vector-oriented studies in future research of elm phloem necrosis. NE(386).

276. The incidence and severity of environmental stresses to which trees are subjected continue to increase with our expanding, urbanizing society. The effects of several kinds of stress were demonstrated to produce a similar disease syndrome. Explanation of the mechanisms by which trees respond

to environmental stresses provides clues for the selection and culture of trees in urban forests. NE(394).

277. Sugar maple borer injury is common in New England hardwood stands. However, the extent and occurrence of damage are not well understood. A damage survey was made on the Bartlett Experimental Forest in New Hampshire in several compartments with differing histories of silvicultural treatments. In contrast to past beliefs, the results indicate that borer injury is not more common on trees exposed by cutting or other disturbance. Forest managers, therefore, need not be overly concerned that exposure of trees by cutting will result in increased injury by sugar maple borer. NE(423,426).

278. Wood discolored by microorganisms can be easily confused with normal heartwood. The formation of both kinds of reactions, and their consequences to tree health and associated wood quality was summarized in a major review article. These guidelines will be useful to pathologists studying wood decay processes and to technologists studying wood utilization. NE(425).

279. The interaction of insects and disease with stress factors such as low vigor results in considerable damage to trees. A literature review on the effects of fertilizers on insects and diseases suggests a complex interaction that warrants consideration before fertilizer is applied. NE(424).

280. The chemical basis for the succession of microorganisms in wounded trees is unclear. Elements such as manganese concentrate in wound-associated tissues that are beginning to decay. Definition of the interaction of manganese with wound-initiated compounds toxic to microorganisms that affect the decay process may provide leads to new methods of preventing wood decay. NE(427).

281. In research of the decay process in living trees, it is difficult to separate those changes that result from the response of the host to the wounds themselves from those that result when the host tissues interact with pioneer-infecting organisms. A plug was designed to allow the exchange of atmospheric air and moisture but suppress infection by microorganisms during the development of discoloration associated with wounds in living trees. The separation of intrinsic host response from microbial-induced response by living trees will enable pathologists to more clearly define the healing mechanisms of trees. NE(420,422).

282. The basis for containment of defect and microorganisms to certain tissues within living trees is not fully understood. Examination of tissues developing from a wound-stimulated cambium revealed the formation of a distinct tissue that compartmentalizes defects. This description of the "healing" process within wounded trees may contribute to the development of more effective ways to cure ornamental trees having internal decay. NE(421).

283. Research discoveries, primarily by USDA Forest Service scientists, about the functions of ectomycorrhizae biological deterrents to feeder root diseases caused by fungal pathogens have been underutilized. Information about ectomycorrhizae has been collated in a textbook chapter that reviews research on this subject. This review has stimulated research and practical application in the biological control of root disease of forest trees. SE(404,405).

284. Information concerning host-parasite relations of nematodes and tree roots is essential to provide a basis for recognition and diagnosis of tree diseases. The role of nematodes as causal agents for tree diseases has been comprehensively reviewed with special attention to their involvement in destroying the resistance of ectomycorrhizae to pathogenic attack. This review of nematodes in forest soils has stimulated new ideas about root disease complexes involving plant-parasitic nematodes, fungal root pathogens, and mycorrhizae. SE(417).

285. Mortality of eastern redcedar caused by annosus root rot occurs in mixed loblolly pine, redcedar stands in the Southeast's Piedmont region. Laboratory and greenhouse studies suggest that loblolly pine is the more susceptible root rot host, but field inoculations indicate that the causal fungus spreads faster through the roots of eastern redcedar. Spread of annosus root rot in clay soils can be affected by growth of *Fomes annosus* in roots of understory vegetation such as eastern redcedar. SE(393,399,400).

286. Poor viability of seed from slash pine seed orchards is a major problem in southern forestry. Radiographic and microscopic examination of slash pine seed lots showed that many seed which appeared full by standard cracking procedures were actually seedbug damaged. Those seed lots in which extensive molding occurred during germination tests possessed greater numbers of seedbug-damaged seed than less moldy seed lots, and the fungi were most frequently isolated from seedbug-damaged seed. Seedbugs are implicated as a major cause of the decreased germination and associated moldy condition of slash pine seed produced in the South's seed orchards. SE(416).

287. A study to define more precisely the role of southern oaks in the life cycles of pine stem rusts and eastern gall rusts was undertaken. It is essential to know the relative susceptibility and telial-production potential of the oak alternate hosts. The relative susceptibility of 21 species of oak to *C. fusiforme* and *C. quercuum* was determined. Scarlet and black oaks were generally hypersensitive to *C. fusiforme*. The black oak group was much more susceptible to both pathogens than the white oak group. This work has clarified the role of several oak species in the epidemiology of fusiform rust and eastern gall rust. SE(378,407).

288. Western gall rust, a damaging disease in the Western and Northern States, has been spreading southward into the Mid-Atlantic States in recent years and might pose a threat to southern pine forests. Experimental inoculations indicate that both slash pine and sand pine can be hosts of this rust. The spores that would spread the disease directly from pine to pine rarely developed in these greenhouse tests. Further experimentation is needed to indicate the variation in pine susceptibility and causal fungus variation, but these intermediate results suggest that the disease would not be likely to spread on southern pines. INT(408).

3. Pest control techniques

289. Controlled release of pheromones and other volatile behavioral chemicals is necessary for efficient application of these materials in the field. Formulations of the cabbage looper (*Trichoplusia ni*) sex pheromone, *cis* -7-dodecenyl acetate, in a polyvinyl chloride plastic matrix remained active for periods as long as 15 months after initial exposure. This method provides a model technique for programming pheromone release of various forest insect bait preparations. Survey trapping for the cabbage looper with pheromones will be simplified if the baits remain attractive for an entire flight season. PNW(311).

290. The introduction of exotic parasites is one approach to checking larch casebearer damage to western larch. A total of 240 *Chrysocharis laricinellae* and 513 *Dicladocerus westwoodii* (Hymenoptera: Eulophidae) from Austria and England were released in Washington and Idaho in 1972. This is the first attempted establishment of these parasites in western

North America for biological control of the larch casebearer. In the long run, parasite introduction could prove the most efficient means of controlling the larch casebearer. PNW(325).

291. The pine root collar weevil, *Hylobius radicis*, destroys young pine plantations in the northeastern United States and Canada. Pruning the lower few whorls of branches of young red pine, plus soil scraping and litter removal around the bole, modifies the adult habitat which results in population reduction. After 5 years, conditions return to near normal, but the trees have increased in size and have partly outgrown the injury. In the next 3 or 4 years before weevil populations could again be destructive, the trees close in and natural population decline occurs. Cultural treatments to alter the adult weevils' habitat can satisfactorily protect pine plantations for the full period of susceptibility. NC(330).

292. Uncertain weather and limited access to infestations can seriously interfere with effective trap-tree programs for control of spruce beetle. Results of studies in Arizona and Colorado indicated that green trees treated with cacodylic acid and felled in the autumn can be about as successful in limiting brood production as are trees treated and felled in the spring. Treating trap trees with cacodylic acid in the fall will greatly extend the amount of time available for doing spruce beetle control work, and should result in more effective control programs. RM(308).

293. There is a real need for nonchemical approaches to control of spruce beetles. The effectiveness of solar heat as a control method has long been discussed. An experiment conducted in Wyoming showed that beetles in infested cull logs in clearcuts can be killed if the logs are turned once by July or earlier. Shade, log orientation, and log position in the cutting area must be considered. In circumstances in which the use of chemicals is undesirable, solar heat appears to offer a potentially useful control method for spruce beetles. RM(316).

294. The mass rearing and release of both domestic and exotic parasitoids of the gypsy moth by several States has created a need for information on the number and relative abundance of domestic and exotic parasitoids in the release area. In a recent evaluation of the relative abundance of the tachinid parasitoids of the gypsy moth on Cape Cod, Massachusetts, *Parasetigena agilis*, *Compsilura cocinnata*, and *Blepharipa scutellata* were found causing significant gypsy moth mortality. *Exorista rossica* and *E. segregata*, from India and Spain, respectively, were not recovered. More extensive collections should be conducted before the exotic species are considered absent from Cape Cod. NE(312,320).

295. The trail pheromone of *Atta texana*, a pest of pine seedlings, is difficult and expensive to produce. Three analogues of the pheromone were found to be nearly as attractive to the ant as the pheromone and are easier to synthesize. If synthesized materials prove to be competitive with the natural pheromone, it should be possible to reduce the cost for leafcutting ant control. SO(326).

296. Attractants are promising agents in pest suppression and survey. Linalool, a terpene alcohol, was isolated from volatiles and frass produced by *Ips paraconfusus* and *I. pini*. Adult beetles of neither species nor sex responded to linalool in laboratory bioassay. Although the function of linalool remains unknown, identification of it moves us closer to the chemical identification of the attractants and attractant-related chemicals of *Ips paraconfusus* and *I. pini* and to the use of attractants in survey and suppression of beetle populations. PSW(331).

297. The aggregation pheromone of *Ips confusus* would be useful for new suppression and survey techniques. Four terpene alcohols and one ketone were isolated from the frass of males boring in pinyon pine. Females responded to one of the alcohols in laboratory bioassay; this response was intensified by the addition of two of the other alcohols. Isolation of chemical components with biological activity from the frass of male beetles advances our knowledge of the biochemical array controlling the behavior of *Ips confusus* and will facilitate research on the identification of other bark beetle pheromones. PSW(332).

298. Recovery procedures for bark beetle pheromones has been slow and expensive. With the use of a cryogenic air liquefaction technique, bark beetle attractants can be identified more quickly, accurately, and cheaply than was possible previously. This major improvement in pheromone research and development should hasten developing programs to survey and reduce bark beetle losses. PSW(307).

299. The prairie tent caterpillar, *Malacosoma californicum lutescens*, is an important defoliator of shrub species in shelterbelts throughout the Great Plains, but there are currently no insecticides registered for use against it. Malathion and diazinon are registered for use against the closely related tent caterpillar *M. C. fragile* (Stretch). The contact toxicity of eight insectidides was compared to malathion as a first step in finding safe effective candidates for suppression of this insect. Five chemicals were more toxic than malathion at LD90: resmethrin, methomyl, pyrethrins, mexacarbate (Zectran), and trichlorfon. Several materials more toxic than malathion warrant further testing in the laboratory and in the field as potentially safe effective sprays for shrubs in shelterbelts infested with *M. C. lutescens* and possibly related varieties of this western tent caterpillar complex. PSW(319).

300. *Malacosoma californicum californicum* is a subspecies in the western tent caterpillar complex common on fruit trees and particularly abundant on coast live oak in California but there are no registered chemical suppression techniques. Ten insecticides were tested topically on larvae of *M. californicum* to compare the response of this insect to that of other *Malacosoma*. At LD50, bioethanomethrin, resmethrin, methomyl, pyrethrins, mexacarbate, carbaryl, and malathion were more toxic than DDT. *M. californicum*, *M. lutescens*, and *M. disstria* differed little in their response to all the chemicals except DDT. Lack of significant inter- and subspecific variation in response to insecticides suggests that enough similarity in susceptibility between species and subspecies exists that data generated for one may be useful in evaluation potential of candidate insecticides against other *Malacosoma* pests. PSW(321).

301. The elm spanworm is a polyphagous defoliator of forest, fruit, and shade trees in the eastern United States which under outbreak conditions can cause serious losses of timber and fruit crops. Ten insecticides were screened as a first step in identifying promising candidates for field testing. Presented in decreasing order of toxicity are bioethanomethrin, resmethrin, pyrethrins, mexacarbate, phoxim, tetrachlorvinphos, DDT, carvaryl, midan, and malathion. Since malathion and carbaryl have given satistactory control in the field, the other insecticides may be regarded as potential candidates for field tests. On the basis of laboratory screening data the pyrethroids, mexacarbate, carbaryl, and malathion have the greatest potential for further research in developing chemical controls for the elm spanworm. PSW(322).

302. It is important to know the potential of the western spruce budworm to develop resistance to Zectran (mexacarbate), which is now registered for use as a replacement for DDT. Throughout 14 generations of treatment, last instar western spruce budworm larvae showed no trend

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toward increased tolerance. Laboratory data suggest that resistance to Zectran would not develop under field conditions and serve as base line information in monitoring for any possible development of resistance under field conditions in years hence. PSW(323).

303. The Douglas-fir tussock moth has exploded to epidemic proportions in the Pacific Northwest and since 1972 has caused tree mortality and severe defoliation on over 800,000 acres; there are no chemicals currently registered for this insect. Of 20 insecticides screened, 11 (bioethanomethrin, the *cis* stereo isomer of resmethrin, the *trans* stereo isomer of resmethrin, resmethrin, pyrethrins, chlorphoxim, methomyl, phoxim, DDT, chlormethylfos, and PhosvelR) were more toxic than the standard, mexacarbate. Dyes and stabilizers needed in field formulations did not impair insecticide toxicity. Several highly promising insecticides warrant further development as tools in chemical suppression of Douglas-fir tussock moth. PSW(324).

304. The transitory nature of pyrethroids requires that they be stabilized to increase their field life if they are to be made more suitable for use in forest insect control. A combination of antioxidants and ultraviolet screening agents in a mineral oil formulation significantly stabilized pyrethroids for 4 hours. The potential usefulness of pyrethrins in forest insect control is greatly improved with new methods of stabilization. NC(314,315).

305. Methods are needed to control insects on newly germinated seedlings in southern forest tree nurseries. Orthene, an organophosphate, produced the best results with excellent penetration into seeds of 5 southern pine species. It had high insect mortality at low dosage rates; and it was not phytotoxic. Southern pine seeds soaked in 1 percent aqueous technical Orthene for 24 hours can be used to protect seedlings for 4 to 5 weeks after germination under nursery conditions. SE(328).

306. Safe, selective, nonpersistent insecticides are needed to control southern forest insects which attack young coniferous seedlings. Monitor, an organophosphate, was absorbed and metabolized in North Carolina loblolly pine seedlings within 6 hours of treatment and remained insecticidally active for 15-30 days. Monitor may be feasible to control pales weevils (*Hylobius pales* Herbst) on loblolly pine when used as a root dip. SE(329).

307. Although the DD-136 nematode is lethal to many insect species, its moisture requirements limit its utility as a control agent. It can move over dry surfaces if the relative humidity exceeds 90 percent, it can survive on foliage in the field for several hours if it is applied at night, and it will last 24 days in bark beetle tunnels in pine bolts. This nematode may be a useful biological control agent in moist areas of the country. SE(309,317).

308. Feeding by the pales weevil may decimate newly planted Christmas trees. Application of granular phorate to Scotch pine seedlings in the nursery failed to increase survival in the field on five sites in Wisconsin subject to attack by the weevil. Further research is necessary to identify an insecticide capable of effectively controlling the pales weevil. SE(327).

309. Methods of applying methoxchlor for control of elm bark beetles have not been adequately explored. The results of a recent study indicate that the type of equipment used to apply the insecticide has a significant effect on deposits, but that the type of emulsifiable formulation has little effect. This information will allow arborists to improve their spray programs to protect trees from Dutch elm disease. NE(310).

310. The forest tent caterpillar annually defoliates large acreages of water tupelo in southern Alabama and Louisiana. Because of the close association of this tree with aquatic environments, care must be taken in developing suppression techniques. Control by ultralow volume applications of rapidly degrading chemical insecticides and by microbial parasites appear particularly promising. Tree defoliation by the forest tent caterpillar was halted by applying only 0.5 to 0.75 lb per acre of active trichlorfon (Dylox-R) (16 oz to 24 oz respectively of ULV formulation containing 4 lb. active per gal). Commercial formulations of *Bacillus thuringiensis* (Dipel R and Thuricide HPC R) gave excellent foliage protection with one aerial application. At the same rates with a molasses sticker, Dipel formulation appears to give better results than Thuricide. Development of effective and environmentally acceptable controls will increase tree growth and assure adequate seed for reproduction of water tupelo following harvest cutting. SO(304,305).

311. Systemic insecticides provide excellent control of insect pests of young cottonwoods, but if misapplied such pesticides can be hazardous to humans and other organisms. A subsoil applicator was developed to provide a safe and effective means for applying toxic systemic insecticides. This subsoil applicator can place granular insecticides as deep as 18 inches in the soil. The applicator is sturdy enough for use in newly cleared land, and is adaptable to commercial operations in both nurseries and plantations. Basically, it consists of an electric granular applicator, two heavy subsoil blades, a stabilizing blade, and a heavy tool-bar mounted on a 3-point hitch for a small tractor. This applicator is designed for young cottonwood stands and it likely can be adapted to a variety of uses where broadcast applications of chemicals are inefficient or environmentally unacceptable. SO(306).

312. Dwarf mistletoes cause an enormous drain on the productivity of western forests. Silvicultural control is possible and ways are being developed to aid managers in determining how and when to apply useful suppression measures. Field procedures were recently published that will aid foresters to utilize the two computer programs for yield simulations of dwarf mistletoe-infested stands: LPMIST for lodgepole pine in the central Rocky Mountains and SWYLD for ponderosa pine in the Southwest. These procedures are now being used operationally in forests to provide managers with guidelines for optimizing silvicultural control of dwarf mistletoes. RM(440).

313. Herbicides would be useful to control mistletoes of high-value trees in recreation sites. Reports from California several years ago suggested that control might be possible with several weed killers. A large-scale test of the most promising chemicals of the California trials (oil soluble amine and butoxyethanol ester of 2,4, 5 tricholorophenoxy butyric acid in concentrations of 0.5, 1.5, and 3.0 percent) was made on southwestern ponderosa pine dwarf mistletoe (*Arceuthobium vaginatum subsp. cryptopodum*) at Bandelier National Monument, New Mexico. Most spray concentrations killed the aerial shoots of dwarf mistletoe, but the endophytic (root) system was not affected and plants soon resprouted. These chemicals cannot be recommended for control of southwestern dwarf mistletoe. RM(443).

314. Scleroderris canker, caused by *Scleroderris lagerbergii*, is causing serious losses in red pine plantations throughout the Lake States. Mortality is high for trees infected as seedlings and planting infected seedlings results in plantation failure. Rapid spread of Scleroderris canker is attributed to movement of infected nursery stock. Studies have shown the fungicide chlorothalonil to be effective for controlling the disease in nurseries. Preventing Scleroderris infection in nurseries is considered the best available means for minimizing spread of and losses from this disease. NC(449).

315. Needle cast, incited by *Lophodermium pinastri*, has caused extensive and severe damage to red and Scotch pines in Lake States forest tree nurseries and Christmas tree plantations. Experiments indicate that the fungicides Fundilan, benomyl, chlorothalonil, and maneb are effective in controlling the disease. Timing spray applications to coincide with major *L. pinastri* spore release periods was successful in reducing the numbers of sprays required for effective control from 17 to 24 down to 3 to 6. This reduces substantially the cost of control and the amount of pesticide applied. With properly applied fungicides, it is still quite practical to grow disease-free planting stock and attractive Christmas trees. NC(446,450).

316. Dutch elm disease, a major cause of elm tree mortality in the United States, cannot easily be controlled. A new method to cure elm trees was tested by injecting MBC-HCl solution into elms. Injection prior to inoculation prevented infection or greatly reduced symptom development dependent upon fungicide concentration. Injection after inoculation at varying stages of symptom development stopped symptom progression in nearly all trees and reversed symptom progression in some trees. With further development, the injection treatment shows great promise for Dutch elm disease control. NE(439).

317. Protecting oaks from infection by the oak wilt fungus has been impractical. The root zone of sand-grown red oak seedlings was drenched with a water suspension of benomyl. No disease symptoms developed in these seedlings following subsequent innoculation with the wilt pathogen. This suggests that the benomyl soil drench treatment could be used to protect urban oaks growing in light soils from the wilt disease. NE(438).

318. Several countries will not import oak logs and lumber from the United States for fear of introducing the fungus that causes oak wilt. Treatments have been developed and tested that kill the organism in logs. They consist of heating the logs in hot air or hot water for specified time-temperature combinations. These treatments may make possible less stringent restrictions on the export of oak. NE(441).

319. A cure for oak wilt in valuable ornamental trees is needed. Injection of a soluble derivative of benomyl into oak trees for prevention or cure of oak wilt was tested. Injection of the MBC-HCl solution into healthy oaks prevented infection from subsequent crown inoculations. Injection of diseased oaks arrested symptom development in some trees but average crown damage was too great to reflect successful treatment. This treatment can prevent wilt infection in oaks and may be of value for protecting shade and other high value trees. NE(442).

320. Some mechanisms suspected as responsible for the resistance of ectomycorrhizae to attack by fungal root pathogens have, heretofore, been too complex to confirm. Using specialized analytical procedures, recent research indicates that specific volatile terpenes produced by pine root cells, in response to symbiotic infection by specific ectomycorrhizal fungi, function as inhibitors to root pathogens. This discovery that gases are involved in resistance of plants to diseases is a key addition to a more complete scientific understanding of disease resistance. SE(433).

321. Littleleaf disease has almost completely eliminated shortleaf pine from forest management in the southern Piedmont of the United States. Field observations indicate that certain shortleaf trees exhibit apparent resistence to this disease complex. The discovery that the relative vigor of shortleaf pine progenies is strongly related to resistance of parent trees suggests that gains in the culture of shortleaf pine may be achieved through genetic selection of outstanding parent trees for seed production. SE(432,452).

322. *Fomes annosus*, a rust rot and one of the world's most damaging forest pathogens, cannot be controlled economically once successfully established in roots of living conifers. In this pilot study, heavy applications of sulfur appeared to check the continued spread of this disease. These results should serve as a basis for critical experimentation to determine kinds and quantities of fertilizer practical for field control of *F. annosus*.. SO(437).

323. Each year, phloem necrosis kills hundreds of ornamental elms as well as elms grown for lumber in Mississippi, Tennessee, Arkansas, and Louisiana. Experiments show that trunk-injections of oxytetracycline, chlorotetracycline, and tetracycline antibiotics suppress disease symptoms on American and cedar elm. About 100 to 500 mg per each inch of tree diameter is needed each year to control the disease. Arborists and pathologists will use this information when developing practical procedures to control elm phloem necrosis. SO(434).

324. Nurserymen in the South have difficulty growing Arizona cypress because of blight disease. To help solve this problem, nonmercuric compounds were tested against Phomopsis blight in a nursery at Winona, Mississippi. Benomyl, 50 percent WP, gave effective control at 1/2 or 1 pound active ingredient per acre and produced no phytotoxicity. Development of safe and effective pesticide treatments will allow nurserymen to produce disease-free planting stock. SO(451).

325. The development of fusiform rust resistant strains of loblolly and slash pines requires a rapid, large-scale method of testing for disease resistance. Research in the Southeast has led to a new system that fulfills the requirements by utilizing a simple method of producing basidiospores and applying them in a water spray suspension. The system provides for the inoculation of several thousand pine seedlings a day and is now operational at the Fusiform Rust Testing Center near Asheville, North Carolina. SE(448).

326. Recent advances in research on fusiform rust were discussed at an international gathering of plant pathologists. Selection for resistance of fast-growing southern pines can now proceed at a rapid rate because of newly developed screening techniques. Plant pathologists need to better understand the potential genetic variation of the pathogen and the mechanisms of resistance so that stability of resistance can be assured. Foresters need better means to rate disease hazard on various sites so that optimal gains are made from a limited, but expanding, supply of disease resistant planting stock. Many of the research approaches developed for fusiform rust will be extended to other pathological problems. SE(447).

327. The identification of mechanisms of resistance operating in slash and loblolly pines is an essential step in selecting and breeding pines with resistance to fusiform rust. Seedlings from certain families of slash and loblolly pines were innoculated with an aqueous suspension of basidiospores of *Cronartium fusiforme* and examined at periodic intervals for symptom development. Purple stem lesions, consisting of relatively small reaction zones of necrotic cortical cells which effectively limited the spread of the fungus, were found on some slash pines and certain families of loblolly pines. This hypersensitivelike response to infection has been demonstrated to be at least one of the mechanisms which render certain pine families relatively resistant to the serious fusiform rust disease. SE(444,445).

328. Injection treatment of hardwood trees with pesticides and fertilizers has been a hit-and-miss proposition because many variables affect the amount of chemical entering the tree. A pressure injector developed at the Southern Hardwoods Laboratory shows great potential for injecting liquid fungicides, insecticides, or fertilizers into trees. It is practical, inexpensive, light in weight, and can be installed on the tree in less than l0 minutes. The total cost of components is approximately $l0. With the injector it is possible to accurately regulate the amount of chemical entering treated trees. The pressure injector appears quite useful for intensive care of valuable trees. SO(435,436).

329. Recent evidence indicates that survival of mountain pine beetle broods in lodgepole pines is related to phloem thickness, yet little is known about this tree characteristic. Studies in Montana and Idaho have shown that phloem thickness is related to measurable tree parameters such as diameter and tree height in conjunction with age. Equations developed from such measurements will aid the development of risk classification for assessing vulnerability of tree stands to insect attack. INT(563).

330. Seed losses due to insects are seriously hindering tree breeding programs with Virginia pine. Control measures are needed that do not use toxic insecticides. In a study in Virginia, screen wire cages were very effective in preventing insect damage to second-year developing cones and increased sound (filled) seed yield per cone from 11.5 to 57.3. Protective screen wire cages should be used on all control pollinations. SE(562).

331. Even with present intensive spray programs using contact fungicides, fusiform rust causes serious losses of seedlings in southern pine nurseries and plantations. Systemic fungicides, which are absorbed by plants through foliage or roots, should give longer and better protection because they are not subject to washoff by rain . Three systemic fungicides were tested in greenhouses and showed potential for preventing rust infection of slash pine seedlings. Two of them are effective in eradicating existing infection. These chemicals will be further tested to verify their suitability for protecting pine seedlings in the nursery and eradicating rust infection in valuable seed orchard or landscape trees. SO(564).

332. Various insect pests may destroy as much as 75 percent of the annual cone crop in southern pine seed orchards. Much of this damage has not been linked to specific insects. A recent study in Louisiana has proved that June bugs (*Phyllophaga micans* Knoch) are responsible for much of these losses during the early spring. Control of this species and other insects is an important aspect in protecting the crop of over 7,000 acres of pine seed orchards destined to produce superior trees for future reforestation in the South. SO(565).

4. Pest management strategies

333. The mountain pine beetle exerts various effects on the lodgepole pine ecosystem, historically depleting stands in the Intermountain Region by periodically killing the largest, most vigorous trees. The loss of trees to mountain pine beetles is partly a function of stand structure. Beetle population survival may be dependent upon either food supply or elevation, according to the particular habitat involved. Knowledge of the interrelationships between beetle populations and stand dynamics can be used to estimate the probability of tree loss, risk of infestation, and brood survival, and provide alternatives for management of lodgepole pine stands. INT(334).

334. Agencies managing public recreation sites are legally responsible for many hazardous conditions, but commonly have no defined approach to hazard control and public safety. Methods for establishing safety standards and the principles involved in evaluating tree-related hazards have been developed at the Pacific Southwest Experiment Station. Adoption of the hazard rating procedures by Federal and State agencies are now resulting in greatly increased levels of public safety at lower costs than would otherwise have been possible. PSW(456).

335. The basic knowledge for silvicultural control of dwarf mistletoes is now available, but these principles are not being widely applied. Some possible reasons include: (1) dwarf mistletoe damage is generally slow and insidious so control is usually not regarded as urgent, (2) limitations on clearcutting have limited some control efforts, and (3) and, perhaps most important, information has not been available as to the yields or benefits and costs of control efforts. Yield simulation procedures have been recently developed by the Rocky Mountain Station for lodgepole and ponderosa pine. These are now being adapted to provide economic analyses for silvicultural control projects. Application of effective controls would greatly extend the timber-producing potential of mistletoe-infested forests. RM(454).

336. White pine blister rust is the most serious disease of eastern white pine in the Lake States. The many substantial studies of the problem have been summarized in a single document. Microclimatic relations are well known, but control is difficult. Antibiotics are not effective, whereas pruning provides some control. Genetic resistance shows much promise but may be complicated by pathogenic races. The most important unanswered question concerns the effectiveness of ribes eradication as a control measure. White pines can be successfully grown in southern parts of the Lake States where rust hazard is low or intermediate. Development of more effective control measures is necessary before planting white pines can be advised for the high rust hazard zones of the northern parts. NC(453).

337. A poor understanding by builders and homeowners about decay prevention and control reduces the service life of wood. The principal moisture situations and construction features most responsible for the occurrence of decay in various building parts are described in a popular manual prepared for all persons interested in wood construction. Architects, builders, and homeowners now have a booklet which gives directions for modifying or eliminating undesirable conditions in existing buildings and construction guidelines to protect wood from decay in new buildings. FPL(457).

338. Comandra blister rust is a troublesome disease of ponderosa and lodgepole pines in the West and of shortleaf and loblolly pines in the East. A control strategy to keep the disease from becoming even more serious should include quarantines, growing of nonhosts in high-hazard sites, maintaining extra stocking to allow for predictable losses, and vegetation manipulation to reduce alternate hosts. Chemical and biological controls and establishment of resistant lines from among susceptible pines are still necessary for a complete and flexible control system. INT(455).

G. Accelerating Forest Resource Surveys

1. Forest inventory

339. In Oregon and Washington the shift of forest land from timber production to other uses such as recreation, road construction, and urban and industrial expansion amounted to over 1.3 million acres between 1945 and 1970. This will have a significant impact upon future timber supplies. PNW(872,878,879).

340. The national trend of reduction of the commercial forest base, but an increase in inventory volume, was reflected in the midsouth. This reflects the growth of young stands and effective forest protection programs. In Alabama, for example, the Nation's third ranking State in terms of commercial forest area, commercial forest land declined 2 percent between 1963 and 1972 due to land use changes; yet softwood volumes increased 30 percent and hardwoods 15 percent. The same conditions, though to a lesser extent were reflected in a midcycle inventory of Mississippi's forests. SO(877,883,885).

341. Although a small state, New Jersey is the most densely populated state of the nation and is still 54 percent covered by forests. As expected, however, the national downward trend in forest area was found there. Between 1955 and 1972, forest area of New Jersey decreased due to land use change by about 10 percent. At the same time, growing-stock volume increased 11 percent, with all of the increase taking place in hardwoods — softwood volumes declined. This reflects a widespread occurrence of young, rapidly growing hardwoods, but little management except for protection from fire, weeds, and diseases. NE(871).

342. Remeasurement of the forests in the Southeast show that in spite of a reduction in the timber growing base due to other land uses such as recreation, agriculture, and urbanization, forest inventory continues to increase, especially in the Piedmont and Mountain areas. This is due to the high proportion of young stands, largely in plantations, which grew from sapling to pole stands during the recent past and to prevention programs which reduced mortality rates caused by fire, insects, and disease. In Georgia, for example, commercial forest area decreased by nearly 1 million acres, or 4 percent, between 1961 and 1972; but timber inventory increased by 29 percent. In the southern coastal plain of North Carolina, commercial forest area declined 5 percent; but timber inventory increased 12 percent. SE(873,874,880,881,882,884).

343. Development and use of southeast Alaska's resources is still rudimentary and well below potential levels. Because of this and because of the unique combination of history, culture, geography, geology, climate, and associated flora and fauna, southeast Alaska represents an almost unprecedented opportunity for innovation in research and management planning. Southeast Alaska's remaining virgin forests have few insect pests; but conversion of these mostly all-aged forests on an extensive basis to new and generally even-aged forests may result in substantially increased insect pest activity. Alternative pest control strategies will have to be evaluated carefully because of the mix of forest values which can be affected. For example, insecticides may be very attractive because they could be brought into operational use rapidly. However, insecticides pose a major long-term threat to the very important salmon resouce of southeast Alaska. Much research remains to be done on other control measures appropriate for the pests and the conditions of southeast Alaska. PNW(875,876).

2. Timber utilization and production

344. During the past decade, forest industry capacity and raw timber consumption in the midsouth have recorded unprecedented expansion. Mississippi's roundwood harvest in 1972, for example, was 36 percent greater than in 1966. Alabama's total roundwood harvest of 735 million cubic feet in 1971 was over 40 percent greater than the harvest in 1963; and Arkansas' timber harvest was up 15 percent over the 5-year period, 1969-1973. Saw logs and pulpwood make up the bulk of this harvest. These increases occurred even though numbers of mills were declining, because average mill size was increasing. SO(887,888).

345. Timber harvest in the Pacific Northwest also continued to rise, but at somewhat lower rates than in the South, registering 7- and 10-percent gains in Washington and Oregon over the 1971-72 period. Of special significance, this increase has come almost solely as a result of increased harvest from public lands. PNW(896,897,898).

346. Studies of forest residues associated with timber harvesting also yield useful data related to forest yield potential. In 1969, 460 million cubic feet of wood fiber suitable for pulping was left after logging in the Douglas-fir region. This is equivalent to 50 percent of the total wood requirements of Oregon's and Washington's pulp and board industry. An additional 239 million cubic feet of forest residue was left in California. In the Southeast about 560 million cubic feet of residue was left in the woods after logging in a recent year; and in Alabama in 1972 about 8 cords per acre were left on clearcutting units after logging. Such volumes may represent added utilization opportunities if prices rise and new cost-effective technologies for utilization are developed. SO(894,895).

347. A strikingly different picture is obtained in some Northern States where both saw-log and pulpwood harvests have declined in recent years, due to some mill closures and a general tightening of supply of better quality timber and desirable species for processing. These in turn reflect changes in land use and a general lack of past management for high-quality products. In 1972 pulpwood production over the entire 21-State Northern area was down slightly (0.5 percent) from 1971, reflecting significant declines in the New England States. Most of the decrease was affected by modest increases in the Lake, Central and Middle Atlantic States. NE(889,890,891,892,893).

3. Survey techniques

348. Some remote sensing applications show promise for forestry work. For example, a pilot study of mapping land uses by computerized multispectral scanning in west Georgia yielded an overall accuracy of 61 percent for eight land use classes considered. Higher accuracies are possible with improved techniques. Microdensitometer analysis methods using large-scale color infrared photographs provide a much quicker method for discriminating shrub and tree species than ground methods. PSW(901,906).

349. Equations for estimating and predicting stocking capacity or productivity on low capacity lands have been developed for California. These may be applied to other areas of low stocking capacity and improve yield estimates. New equations employing plant indicators have been developed for the Northwest for predicting site index and yield. Equations for predicting tree volumes in the Northeast and the West were also developed. PNW(899,900,902,903,904,905,907).

350. A model has been developed simulating forest succession over large areas. Several northern Michigan forests were used as examples of this technique. Changes in the model necessary to include the influences of management, fire, and epidemics are indicated. Such models are valuable for analysis of regional dynamics, land-use planning, and development of regional management strategies. NC(566).

H. Economics of Forest Management

1. Methods of financial evaluation and planning

351. Allowable cut on federal lands in the Douglas-fir region increases when calculated on a cubic-foot basis instead of the traditional board-foot basis. In addition, calculation of allowa-

ble cuts under volume regulation magnifies the advantages of investments that increase tree growth. When including the allowable cut effect in evaluating stand treatments, expanding the treatment analysis to include effects on the firm's total costs and incomes would make the economic analysis more complete. NC(910,918,920,927).

352. A study of methods of scheduling thinnings in the Tillamook Resource Area of Oregon showed how net returns from thinning programs could be increased. The approach applies mathematical programming to optimize thinning priorities in Douglas-fir. Budget levels also influence whether assigned quota of thinning volumes can be met. Applying mathematical programming methods and results requires close cooperation of forest managers and researchers. INT(909,911,912,917,919).

353. In the South, development of techniques for simultaneously estimating saw log and pulpwood volumes in truckloads is improving wood measurement in tree length logging. A computer program developed to analyze sample data produces two estimating equations (to predict volume and weight of saw logs) and a set of administrative tables to predict saw log and pulpwood volume for any potential load that falls within the range of sample data. Check scaling should be carried out continuously to validate the constants of the predicting equation. SO(914,915).

354. Logging cost information is scant for young-growth mixed conifer stands in California. Production rates determined by time studies in California for each operation in logging, including delivery to landings, showed that rates were best for the more tolerant species. Production for a turn of logs averaging 22 inches d.i.b. was 2 1/2 times better than one averaging 12 inches d.i.b. Results showed that there are relatively large differences in tree size in young-growth timber, and that these differences play a major role in determining logging production rates and costs. PSW(567,568).

2. Timber growing economics

355. Methods developed for calculating immediate and future losses caused by the gypsy moth in the Northeast indicated value losses to commercial forest stands and to residential property. For each residential area infested, the method used number of trees injured and lot size to determine effects on current property values. For forest stands, discounting of future losses evaluated the insect's impact in terms of income potential. The research discusses the effect of infestation on forest management and presented a format for making control decisions. NE(924,925).

356. Life insurance companies in the South have accepted more and more forest land and timber as loan security since 1950. Loans have been granted to individuals, co-owners, partnerships, corporations, and trusts, but only where timber markets were well established and production profitable. Refinancing other debt was the main reason for borrowing. Only 2 percent of the borrowers invested in forestry related activities. Most loans, however, indirectly influenced forest management since requirements specify that the woodlands be well managed and protected. SO(929).

357. Site value taxation of forest land in the United States appeared administratively feasible and resource allocation effects, provided land use controls were effective, likely to be favorable. Forest lands, however, raised questions not encountered in the site value taxation of urban property; empirical studies of forest land applications were needed. WO(923,926,928,930).

3. Multiple-use economics

358. Economic values for all resources in evaluating alternative land use policies on the National Forests can be estimated using operations research techniques. A linear programming case study of the Mogollon Rim area of Arizona analyzed water, wood, range, and outdoor recreation alternatives. The value of an additional unit of resource output fell between the price actually paid and the ability to pay of the average purchaser or user. RM(934).

359. Analysis of trade offs between recreation and timber production can determine the most financially rewarding alternative to owners. In a study of cost and returns for a southern hardwood tract, an anticipated stumpage price of $40 per thousand board feet or more indicated the most profitable option was emphasis on timber production. If stumpage prices were less than $40, the owner should be advised to seek opportunities for recreation-for-pay uses. SO(931,932,933,935).

4. Impacts on forest industry and regional economics

360. For the economy of Douglas County, Oregon, an input-output study described in detail the interrelationships of each economic sector and traced economic impacts of forest management decisions. The economy was shown to be highly dependent on timber and related wood processing industries. Researchers in the Northwest found, however, that employment in timber-dependent industries in the Douglas-fir region declined slightly from 1959 to 1971. Only in 3 of the 14 economic areas in the region did employment match national trends in these industries. INT(946,947).

361. Medium-sized sawmills can use linear programming to analyze proposed improvements and to determine stumpage-buying strategy. In a case study of a southern mill, linear programming analysis suggested that the sawmill install a second gangsaw, realign the cutoff saw, and sell small logs as pulpwood. As a result, revenue increased by 45 percent and volume processed increased by more than 36 percent over existing values. Stumpage-buying strategy was determined from the data of log classes sensitive to price changes. SO(938).

362. Labor organization in the timber harvesting industry has been influential only in western integrated logging-processing operations; other areas in the United States having small and scattered production units, unstable employment, surplus rural labor, and other factors are not conducive to unionization. Efforts to organize independent loggers and their workers in the Lake States and South have been ineffective due to competitive conditions and legal barriers. Though the potential for increased unionization of woods labor appears limited, several current trends are favorable to organizing activity. Among them are greater mechanization, more harvesting by company crews, and mergers of forest industry firms. SO(940).

363. In the Northeast, an improved statistical technique utilizing factor and cluster analysis classified the counties in the 13 state region into 8 homogeneous subareas. These areas were based upon a variety of physical, economic, and demographic variables related to conditions influencing type and extent of timber activities. Subsequent studies using these subareas will be more meaningful since results can be related to unique characteristics. NE(937,939,941,942,945).

I. Improving Engineering Systems

364. Estimates of dynamic weights and center of gravity of trees are important in the development of multifunctional

logging equipment. A theoretical method for estimating the mass moments of inertia of full trees and boles about a transverse axis was developed. Estimates from the theoretical model compared closely with experimental data on aspen and red pine trees obtained in the field by the pendulum method. The theoretical method presented may be used to estimate the mass moments of inertia of other tree species for which field data are not available. NC(1042).

365. To promote increased utilization, factors that affect logging production must be understood. Prediction equations relating stand, terrain, and climatic factors showed that the most important factors affecting productivity of tree-length aspen were the ratio of harvested trees per acre to total trees per acre, harvested volume per acre, and the spacing of non-harvested trees. This information is useful not only to the logger himself, but also to equipment designers, systems analysts, and resource planners who must know what stands of aspen are economically harvestable. NC(1023).

366. Two 750 cubic foot piles of unbarked chips were stored for one year near L'Anse, Michigan, to evaluate the effect of chip storage on the effectiveness of barkchip separation-segregation methods under study. One of the piles was aspen (*Populus tremuloides*) and the other jack pine (*Pinus banksiana*). In processing, stored chips suffered more wood loss than fresh chips. On the basis of this study, whole-tree chips should be processed when received and the clean chips stored if storage is necessary. NC(1038).

367. Commercially available portable chippers permit whole-tree utilization in the production of wood chips. Methods must be developed, however, for removal of bark from whole-tree chips or residue chips before they will be widely accepted by the pulp and paper industry. Processing and conditioning treatments before and after compression debarking of western hemlock, Douglas-fir, red alder, and bigleaf maple were studied. Bark removal and wood recovery from red alder far exceeded the other species tested; approximately 90 percent of the wood fiber input was recovered at a residual bark content of less than 2 percent by weight. NC(1033).

368. Equipment for harvesting, chipping, and transporting whole trees from the stump to the pulpmill is now commercially available. One deterrent to widespread utilization of this system is the difficulty in removing bark and foliage after chipping in the field. Rotary screening is one potential method. Two sizes of rotary bar screens were tested on four northern conifers; jack pine, red pine, white spruce, and balsam fir. Foliage removal ranged from 57 to 76 percent, and bark removal ranged from 22 to 31 percent, depending on species. Principal advantages of the rotary screen method are that the screen can be cleaned continuously and screening is done according to thickness of the material, which is the most critical dimension of pulp chips. Another advantage is that the rotary screens are adaptable for field operations. NC(1043).

369. Technology is available to field chip a felled tree, but systems must be developed to remove bark and foliage from chips. Questions concerning the economics of such a system and quality of material produced, must be answered before pulp companies can justify large capital expenditures in a new wood-supply system. We estimate that whole-tree chipping followed by bark removal is $3 per cord less costly than conventional chips produced from debarked roundwood. A 2 to 3 cord per hour continuous processing pilot plant is the next step needed to provide production and cost data to support the design and establishment of a full-scale production plant. NC(1022).

370. Whole-tree chipping is a new harvesting system which results in greater utilization of the existing timber resource. Nearly 60 percent increase in pulpwood yield was obtained in one test run in southern pine. The increased yield is obtained by harvesting and chipping the tops and limbs of large trees and most of the small trees that normally would remain after conventional pulpwood harvests. NC(1029).

371. A process to remove the bark from wood chips by breaking the bond between the bark and wood fractions followed by segregation of the bark particles from the clean wood chips includes the steps of: steaming the wood chip mass to weaken the bark-wood bond and render the bark tacky; mechanically compressing the chips to partially break the bond between the bark and wood and to break a portion of the bark fraction into smaller particles; removing these particles, some of which adhere to the compressing medium, from further processing; subjecting the partially beneficiated chips to unique abrasion or milling processes to fragmentize the remaining bark; and segregating the resulting clean wood chips from the fragmented bark. The sequence of steps may be varied and the bark is removed from processing at different stages. NC(1035).

372. Mechanical tree shakers provide an effective method of collecting cones, but the influence of the resulting high-frequency vibrations on future tree growth and cone production is unknown. A recently completed study of 31-year-old slash pine trees in central Louisiana showed that mechanical shaking did not adversely affect either flower and cone production or height and diameter growth. Slash pine seed collection is valued at $1.5 million annually in the South. Tree shakers can be safely used to harvest this crop. SO(1039).

373. How are current logging practices influencing timber utilization? In Alabama, research showed that new technology has boosted logging efficiency, increasing the yield from mid-South forests by 7 percent in the past 8 years. Increased efficiencies resulted from cutting lower stumps and closer use of bole sections through multiproduct allocation. On clearcut areas in 1972, about 8 cords per acre were left in residual trees, tops of cut trees, unused bole sections, and above ground parts of stumps. These data from current logging practices will aid land managers, loggers, procurement personnel, and utilization specialists in developing better systems for harvesting our timber resources. This will result in improvements in timber utilization, thereby extending our present timber supply. SO(1018,1019,1027).

374. Labor for timber harvest is in short supply and mechanization in the harvesting of naval stores is vital to insure growth and stabilization within the industry. A levered walking machine may be feasible not only in the naval stores industry, but in other forestry applications in the future. The concept was developed to increase alternatives in various stages of full mechanization. SO(1025).

375. The problems of logging swamplands in the south include movement made difficult by water and mud and zero slope. A satisfactory logging system must have low capital investment, be economic in small diameter stands, easy to install and use, and nonlabor intensive. This review of the potentials of cable logging systems for wet lands should assist forest industry in developing new or improved logging methods. SO(1028).

376. Present utilization standards and logging practices leave large amounts of residue on the ground after harvesting. Although some residue in the form of small branches and leaves must be beneficially left on the ground, large amounts create a fire hazard, inhibit regeneration, and destroy esthetic

values. Harvesting of lodgepole pine in Wyoming for near complete utilization (including limbs, tops, and cull material) increased total wood yield by 35 percent. Logging costs for conventional and near complete harvesting of merchantable material were nearly the same. The cost of harvesting and removing residue seems favorable and promises to provide better utilization in the near future. INT(1030).

377. A logging system designer must know what payload a logging system can carry over a given ground profile. A computer program was prepared to determine the running skyline load carrying capabilities. This program should aid the logging layout designer with his planning task. PNW(1026).

378. Managers and planners of forest operations must have a planning and scheduling tool that assists them with two major aspects of the project: (1) accountability for various phases of the project, and (2) determination of whether existing resources are satisfactory. A technique using a restricted resource algorithm to optimize the project's duration, given a limited resource pool, was developed for planning and scheduling operations. PNW(1024).

379. Tethered balloons are used to yard logs in the Pacific Northwest. They permit harvesting in difficult terrain with little impact on the forest environment. Knowledge of the aerodynamic characteristics of balloons at a wide range of attack angles is needed to design the optimum system configuration. Data from wind tunnel tests on lift, drag, and pitching moment were developed for an angle-of-attack range of 12o to 102o. Results are for natural shape, barrage, class C and Vee balloons. Also the use of each shape as a tethered balloon is discussed. PNW(1040).

380. The three balloon logging systems operating in Idaho, Oregon, and Alaska in 1972 were reviewed, with a summary of major rigging methods, environmental problems, and current operator efforts toward greater efficiency. A detailed compilation of 1972 yarding production data includes total volume, logs, operating hours, turns, and acres. PNW(1041).

381. The basic tight, slack, and running skyline yarding systems were evaluated according to environmental and silvicultural criteria, economic criteria, and physical criteria. By using realistic criteria, the most suitable means of yarding can be selected. Several misconceptions concerning skyline logging were clarified. PNW(1037).

382. The Applachian logger, in attempting to select a cable logging system which is less damaging to the land than existing tractor systems, is confronted with a number of different cable systems with differing characteristics, costs, and requirements. Five cable systems, thought to be feasible for Appalachian use, were analyzed with respect to equipment features, environmental factors, and road requirements and a method of comparing cable systems presented. This method of comparison and analysis gives the Appalachian logger a reference guide he can use to select a cable logging system to best fit his situation. NE(1031).

383. Since reliable results from simulation models (e.g. of timber harvesting systems) depend on how long the model runs, that is, how many days, weeks, or other time periods are simulated by the computer, it is important from an efficient programming and computer usage standpoint to have some means of estimating the necessary model run time. Construction of confidence intervals about critical output parameters makes it possible to determine when results are reliable. The amount of computer time needed to obtain reliable results will depend on model variability, prescribed width of the confidence interval, and level of confidence of the simulation model. NE(1032).

384. Loggers and timber harvesting researchers have needed an analytic method of comparing different logging systems (new and old) without purchasing expensive equipment or conducting long term tests. A mathematical simulation method was developed that compares logging systems for cost and productivity. This simulator has been modified to include skyline systems, and costs for one skyline are reported. Simulation results cannot replace actual logging costs, but they do provide valuable information at low cost on both experimental and conventional logging systems. NE(1021).

385. The tires used on most Appalachian log skidders are too small for the loads they carry and usually are underinflated. Correct tire sizes and inflation pressures were calculated and plotted for different log skidders commonly used in the area. Using these tables, the logger can determine the correct tire size and inflation pressure for his machines which will extend tire life, reduce the number of tire failures, and lower his cost of logging. NE(1020).

386. Portable power sources are very useful in forestry operations. A small experimental gas generator and test bed were developed. The generator's performance with unheated and heated inert gases was satisfactory up to gas temperatures of 200oF and pressures to 129 psig. Evaluation of exotic fuels is a necessary prerequisitie toward the possible development of gas generators as a power source. NE(1036).

J. Improving Water Quality

1. Managing, rehabilitating, and improving watersheds

387. Rapid establishment of a vegetative cover on strip-mine spoil banks is needed for erosion control and watershed protection. A study in Pennsylvania indicates that lime is the most essential amendment for establishment of red pine and Japanese larch on anthracite coal-mine spoils. After 4 years the surface zones of plots limed at 5 tons/acre were still in the neutral pH range. Commercial fertilizer had only a slight effect on growth and had no effect on survival. Mulching improved overall survival. As a rule, natural vegetation and planted trees and shrubs have not survived on these spoils. NE(32).

388. A survey of 39 surface mines in southern West Virginia showed that most of the spoils from current mining operations had a pH of 5.0 or higher. Soil-size particles constituted 37 percent of the weight of the spoils sampled. A major problem in the establishment of vegetation was a deficiency of nitrogen and phosphorus. This, however, can be corrected by adding fertilizer at appropriate rates. NE(68).

389. Flow in streams following storms changed very little after trees and vegetation vere removed from a small mountainous watershed in New Hampshire. Spring and summer increases in stormflow were small but readily detectable. The relatively small amount of cutting of forests and their quick revegetation in New England headwaters should not increase potentials for floods. NE(47).

390. Many areas strip-mined for coal have serious revegetation problems. The success of planted seedlings may depend on their physiologic efficiency in coping with adverse conditions. Several of 57 Virginia pine progeny from 10 natural stands in Tennessee and Kentucky evaluated under field and greenhouse conditions were definitely superior for planting on toxic spoil. The findings may lead to a breeding program to produce genotypes specifically adapted to adverse sites, resulting in substantial improvement in revegetation success. NE(67).

391. Small gaged watersheds in West Virginia were used to evaluate the effects of deforestation. Soil moisture, precipitation, and streamflow were measured on three watersheds. Two of the watersheds had been deforested and treated with herbicide to prevent regrowth for 6 years and one kept as a forest control. Streamflow increased 10 inches annually on the cleared watersheds. Water content of the bare soil always exceeded that of the forested soil throughout the growing season, and the higher moisture content resulted in larger instantaneous peak flows during small storms. Peak runoff was minor for large storms and in all storms during the dormant season. This study provides a better understanding of the components of water balance equations and how they relate to each other. NE(63).

392. After one growing season, black locust seeded on coal spoil banks in eastern Kentucky and fertilized with phosphorus averaged three to four times taller than those seeded on unfertilized plots. Adding nitrogen with phosphorus produced even greater growth. The black locust was seeded with four types of herbaceous species which, when fertilized, competed with the locust seedlings. Competition was less severe when black locust was seeded with slower developing herbaceous species, or with species that grow in late spring and summer. NE(86).

393. Logging and road building affect streamflow, sedimentation, and aquatic habitat in forested watersheds. But how decisive are the impacts, and how long must effects be studied to be considered significant? In 1960 a study was initiated on these effects on two experimental watersheds in northern California. Effects of road construction were studied during a 4-year period. In three of the four years, construction of roads and bridges resulted in above normal yields of sediment, but impacts were minimal on streamflow, fish habitat, and fish populations. Long term effects of logging and road building remain to be established. PSW(53).

394. Portable lysimeters were found to be valuable instruments for measuring snow melt under severe temperatures in central Colorado. Obtaining accurate estimates of daily melt of snow is simplified because snow rarely melts during the night. Since free water usually drains from the pack by the following morning it is not necessary to correct for melt water retained within the lysimeters. The lysimeter frame did not noticeably affect the thermal regime of the snow. Comparison between lysimeter and snow-tube measurements of melt rates established that lysimeters provided reliable measurements of melt rates. RM(75).

395. Some land management decisions require information based on soil water retention data. For this purpose, an interaction model was developed that allows predicting water retention for coarse textured soils. Organic matter content, amount of fine particles, and soil density were found to influence water retention levels. Knowledge of such soil properties is useful to the silviculturalist planning for regeneration and to the watershed specialist concerned with changes in water yield. INT(30).

396. Sound environmental forestry requires knowledge about hydrologic implications of cutting and burning of forests. Clearcutting an oak-hickory forest in southwestern Wisconsin caused no increase in soil freezing and overland flow of water, whereas, complete litter removal and complete vegetation removal did increase freezing and overland flows. Logging operations in hardwood forests on sloping land in the upper Midwest that do not destroy the ground cover can be compatible with good watershed management. NC(71).

397. Snow fences built upwind of natural snowdrifts in the Colorado Rocky Mountains can substantially increase accumulating snow. By changing the distribution of the snowpack in alpine areas, accumulation of water in the snowpack can be increased appreciably. Three-meter (10-foot) tall wood slat and wire snow fences, the type studied for this report, if properly located, are a means of augmenting summer streamflow from alpine areas. RM(61).

398. A simulation model was designed to determine probable hydrologic change resulting from watershed management in the Colorado subalpine zone. The model simulates the total water balance on a continuous year-round basis, and it presents an overview of an entire drainage basin. This model is a unique tool for objectively evaluating potential hydrologic effects of activities in management of watershed resources. RM(55).

399. In the relatively warm climate of the Southwest, it is generally unknown how increased snowfall may affect forests in the subalpine ecosystem. Growth of Engelmann spruce was examined where snowdrifts were shallow and deep. Based on this study, modest increases in annual snowfall, resulting from weather modification programs in the Southwest, will have little detrimental effect on the annual or long-term growth of existing forests. RM(41).

400. A new snow fence designed to reduce costs of snow removal has proven extremely effective in improving visibility during blizzards and in reducing ice formation on road surfaces. Innovations in the design included revisions of fence configuration for greater efficiency, use of 12-foot-tall fences rather than shorter fences previously adopted as standard, placement for greater storage capacity, and calculation of required storage capacities of each new fence system. Timely application of these research results in Wyoming is saving lives and dollars. RM(79).

401. Studies in southeastern Wyoming show that snow can evaporate completely when blown over distances of 3,500 to 4,500 feet. Where distances of transport are long, up to 83 percent of the relocated snow is evaporated back to the atmosphere. Snow fences located at distances suggested by this research could increase accumulation and storage of snow up to 300 percent on the high plains and nonforested mountainous areas. RM(80).

2. Preventing watershed damage

402. Strip mining in Appalachia is generally considered to have adversely affected the hydrology of watersheds. Data from watersheds in Kentucky show that stream turbidity and peak flows increased during mining, but turbidity returned to premining levels within about six months. Duration of runoff from storms did not change after mining. Sulfate and magnesium in the streamflow increased for years after mining. The scope of this study includes determination of changes in the water resource after strip mining, but not the evaluation of the changes—whether harmful or beneficial. NE(92).

403. Frozen ground affects runoff of snowmelt and contributes importantly to floods in the spring. Under certain conditions in southwest Wisconsin, potentials for runoff differ significantly on north- versus south-facing slopes because of differences in depth of soil frost. Knowledge of these differences can be useful in assessing the potentials for flooding in the spring from the steep, unglaciated region of the upper Midwest. NC(102).

404. An accurate evaluation of hazards due to avalanches is one effective way to reduce damage by avalanches. In the

Front Range of Colorado, 19 weather factors were analyzed to determine their correlation to avalanches. A storm index, based on intensity of precipitation and windspeed, was developed to predict the number of avalanches on 23 paths. Although developed for Colorado, these predictive aids appear to be adaptable to many mountain areas of western United States. RM(101).

405. Contour trenching after severe overgrazing, fire, or drastic disturbance is used to stabilize soil in the Intermountain West until protective vegetation is re-established. Precipitation caught in these trenches has been thought to evaporate in amounts sufficient to significantly reduce total water yields. Results from a recent study in northern Utah show that trenching has no significant effect on water yields and timing of flows, and that sediment and peak flows are not drastically reduced. INT(91,98,100,103,104).

3. Water quality

406. Water quality of forest streams in western Oregon can be markedly influenced by the type of forest management activity. On the H. J. Andrews Experimental Forest, frequency of landslides larger than 100 cubic yards increased dramatically on slopes greater than 40 percent. In two separate studies, roads and especially road failures drastically increased concentrations of suspended sediment. Clearcutting and slash burning produced considerably less sediment than roads. Highest concentrations of native nutrients appeared in streams after slash burning on clearcut watersheds. Nutrient outflow declined with revegetation. Such studies can demonstrate to managers certain activities and practices which must be done with greatest care in order to avoid pollution of streams. PNW(106).

407. Forest fertilization may cause a decline in quantity and quality of streamflow. Greater water losses to transpiration and evaporation may result from additional leaves and roots. Water quality may be adversely affected by application of fertilizers into streams and by an increase of nutrients transported to streams by subsurface flow. Nutrients in subsurface flow are determined by such factors as type, form, and quantity of fertilizer applied, efficiency of root uptake, climatic conditions, and cation exchange capacity of the site. These factors should be appraised before fertilizers are widely used. NE(107).

408. Both loss of nutrient ions from burned forest land and use of nitrogen fertilizer in conjunction with seeding will adversely affect water quality. During 2 years of study in north-central Washington, nitrates in streamflow increased from background levels of 0.005 parts per million (ppm) in a control stream to 0.042 and 0.310 ppm in streams flowing from watersheds that had been burned and both burned and fertilized. Neither burning nor fertilizing with urea caused increases in nitrogenous constituents to occur at levels above those recommended for municipal water supplies. Losses of nitrates from the burned watersheds will negligibly affect future productivity of these forest ecosystems. PNW(111).

409. The hydrologic response of eradicating big sagebrush with a herbicide was evaluated in south central Wyoming. Soil moisture withdrawal was reduced 24 percent. About 83 percent of the reduction accrued below the 2-foot depth. Spraying reduced production of herbs and forbs about 63 percent, while production of grass increased 20 percent. Control of sagebrush can greatly increase the soil moisture regime where sagebrush is dense, soils are deep, and snowmelt is sufficient to fully recharge the soil mantle. RM(105,108,110).

K. Bettering Silvicultural Systems

1. Natural regeneration

410. Natural lodgepole pine regeneration on pumice soils in southern Oregon may require decades to become established because good seed years often do not coincide with favorable moisture and temperature regimes. A series of closely related studies generated the following limited alternatives for the timber manager for restocking problem areas where regeneration failures are common: (1) rely on planting, (2) leave a light cover of slash for seedling protection, (3) convert the more severe sites to uses other than timber production, and (4) make allowances in timber management plans to provide for lengthy regeneration-establishment periods. PNW(570).

411. Little information has been available on seed production and seed dispersal into clearcuts for species comprising the true fir-hemlock forests of the Pacific Northwest. Studies in Oregon and Washington showed that adequate cone crops were produced at 2- to 3-year intervals, and that seed dispersal decreased rapidly beyond one tree height from the stand edge (125 feet). Such information will aid land managers in designing size, shape, and type of cutting in fir-hemlock forests. PNW(573,574,575).

412. Regeneration failures after clearcutting Douglas-fir at high elevations in the Oregon Cascades led the Forest Service to try shelterwood harvesting beginning in 1962. A survey of 21 operational seed tree and shelterwood units consistently showed satisfactory stocking in the shelterwood units. Shelterwood cuttings and attendant good site preparation which exposed mineral soil improved the microclimate for germination and seedling establishment. Seed tree cuttings were less successful despite good site preparation. Thus, shelterwood harvesting is a viable alternative to clearcut harvesting on these high elevation sites. PNW(581).

413. Regeneration of trembling aspen on disturbed areas depends on root suckering, but relatively little research has been conducted on the species in Alaska. Sucker development in a controlled environment was best when temperatures varied between a maximum of 25-30o and a minimum of 15-20oC. Suckering was also influenced by root collection dates and clones, but was not affected by time of site disturbance or carbohydrate reserves. These findings will aid aspen management, particularly in cooler climates. PNW(580,583).

414. Infrequent cone crops of white spruce in Alaska emphasize the importance of proper collection and storage conditions of cones to maintain adequate seed inventories. Seeds in cones collected early (before August 5-12) germinated better when stored outdoors. However, seed was able to withstand adverse storage conditions best when cones were collected within 1 week of natural seedfall. Seed collection guidelines derived from study results will increase the probability of obtaining a viable seed supply. PNW(582).

415. A joint effort by the Minnesota Department of Natural Resources and USDA Forest Service established the Big Falls Experimental Forest in 1948 to learn more about black spruce peatlands. Now, after 25 years of Federal-State cooperation, some important findings show that tree growth depends on nutrient- enriched water from uplands, pulpwood yield is greater from even-aged forests, and clearcuts can be regenerated best following broadcast burning of slash. Current studies promise to provide additional information in the future, meanwhile the area continues to serve as a demonstration forest for management practices. NC(577).

416. Tamarack, an important conifer on peatlands in the Lake States, does not regenerate well on clearcuts because dense brush, slash, and moss seedbeds hinder seedling establishment. Research in Minnesota, however, indicates that seedlings become established in sufficient numbers to satisfactorily restock clearcuts if the area is broadcast-burned and seed-bearing trees are left standing within about 200 feet of seedbeds. With such information, tamarack can be favored in management, or if desired, the forest manager may regenerate the area with associated species, such as black spruce, by removing tamarack seed-bearing trees. NC(578).

417. Little information is available concerning the age, growth characteristics, and origins of regeneration in spruce-fir stands in the Northeast following cutting. Recent studies in south-central Maine showed that very few potential crop-tree seedlings occurred as advance regeneration. This suggests that regeneration arising before harvesting cannot be relied upon to provide the growing stock for new forests without some modification of the forest canopy through intermediate harvests or natural causes. NE(569).

418. A practical guide to the silvicultural treatment of spruce-fir stands for timber production in New England and New York has been prepared. Both even-aged and uneven-aged management are considered, covering both the establishment of new stands and the culture of existing stands. A set of prescriptions describing specific treatments for a variety of stand conditions and management objectives is included. NE(572).

419. Many clearcuttings made in the Allegheny hardwood type over the past 4 or 5 years have failed to regenerate satisfactorily, because the stands lacked adequate numbers of advance seedlings prior to cutting. Furthermore, there have been no guides available as to the amount and distribution of advance seedlings required. A recent study has shown that there should be at least 15 black cherry advance seedlings or at least 80 advance seedlings of any desirable species on at least 70 percent of 6-foot-radius plots sampled prior to cutting. If cutting is restricted to stands containing these amounts of advance seedlings, regeneration success of over 90 percent can be expected. NE(576).

420. The role of site index, stand density, and tree age on cone and seed production of longleaf pine is not well defined. In a south Alabama study few cones were produced in stands less than 30 years of age. In stands 30 to 70 years in age, production increased with increasing site index and decreased as stand density increased above 30 square feet of basal area per acre. The number of seeds per cone averaged 50 in good years, 35 in average, and 15 in poor years. These results provide essential information for planning natural regeneration and cone collection operations. SO(571).

421. The success of natural slash pine regeneration with two-stage harvesting in the West Gulf has not been determined. Height and basal area growth of natural regeneration were the same regardless of whether overstories contained 5, 10, or 20 trees per acre or had been removed completely. Growth of seedlings and saplings was not appreciably reduced when the overstory removal was delayed for 12 years. Seed tree and light shelterwood systems appear to be acceptable alternatives to clearcutting slash pine in Louisiana and East Texas. SO(579,592,597).

2. Silvicultural methods

422. Although herbicides have been used for over a decade as a silvicultural tool in management of coastal Oregon and Washington forests, published information on response of shrubs is limited. Of 15 herbicides or combinations of herbicides tested in Oregon, picloram produced the best overall control of six species when applied in late spring, but foliage sprays of 2,4,5-T were also effective. Results of these screening tests provide a sound basis for prescribing treatments suitable for site preparation and conifer release. PNW(594,598).

423. Ponderosa pine is one of the most important softwood species in the United States. Because of its extensive range and economic importance considerable research has been conducted on this valuable species. Bibliographies listing early research were compiled in 1949 and 1967. A supplemental bibliography including 732 research references published between 1966 and 1970 is now available for scientists, students, and scholars. INT(585).

424. Guidelines are needed to aid the forest manager in developing partial cutting practices in converting old-growth Engelmann spruce—subalpine fir forests into managed stands, while maintaining continuous forest cover in areas of high recreational value or outstanding scenic beauty. In these reports, guidelines which consider stand conditions, windfall risk, and insect susceptibility are presented. Suggested cutting practices which can be used in combination with small cleared openings to create the kinds of stands desirable for increased water yields, to improve wildlife habitat, and to integrate timber production with other uses are discussed. RM(584,589,590).

425. In response to the need to provide viable silvicultural alternatives for resource managers, a preliminary guide has been developed for establishing even-age northern hardwood stands by the shelterwood method. Detailed instructions and explanations are presented for use of the shelterwood method to produce both tolerant and intolerant species. NC(593).

426. Northern hardwood forests require silvicultural methods which will improve timber quality and enhance the quality of the forest environment. Results of pilot studies show that a balanced stand structure with 80 square feet of basal area per acre and 10- to 20-year cutting cycles under the selection system provides for steady wood production of sugar maple and other shade-tolerant species. The system also causes very little disturbance in the forest canopy; its application is especially useful in scenically sensitive areas. Clear-cutting in blocks, strips, or patches, however, works well for the more light-demanding species: yellow birch, paper birch, and white ash. NE(591).

427. Control of stocking is one of the fundamanetal tools of silviculture, yet a stocking guide had never been developed for eastern white pine. Based on crown dimensions of dominant trees, a chart has been developed showing basal areas and numbers of trees by mean stand diameter representing the upper limit of stocking for practical management (curve A) and minimum stocking (curve B) for full site utilization. The guide provides for the first time an objective means for controlling stocking of eastern white pine during thinning operations. NE(595,596).

428. Regeneration of Appalachian hardwoods is influenced by site quality and harvesting method. Tolerant species predominate following selection cuttings: sugar maple, sweet birch, and beech on excellent sites and red maple, sweet birch, and beech on fair sites. A good representation of intolerants as well as tolerants can be expected after clear-cutting. Yellow-poplar and black cherry will be well represented on excellent sites and on fair sites a variable number of oak stems can be expected. NE(599,600).

429. Natural pine regeneration on abandoned farms in the Georgia Piedmont has contributed greatly to the economy and well-being of the area and its people. A recent monograph assembles environmental information and evaluates different methods of loblolly pine management such as clearcutting and planting, seed tree and shelterwood regeneration cuttings, and selection cutting. This book will assist practicing foresters, researchers, and landowners in managing loblolly pine for multiple use and multiple products. SE(586,587).

430. A landowner has many options for regenerating southern pines. Fourteen studies comparing loblolly pine regeneration methods in Louisiana and Texas showed that planting is the most reliable regeneration method, and that direct seeding is preferable to natural seeding. Results demonstrate that loblolly pine can be successfully regenerated by all three methods. If sites are properly prepared and the seed distributed under favorable environmental conditions, direct seeding can be as effective as planting with a considerable savings in cost. SO(588).

3. Ecological relationships

431. Abrupt boundaries between lodgepole and ponderosa pine stands in south-central Oregon often occur with slight changes in topography. Tolerance to low nighttime temperature appears to be a controlling factor—lodgepole pines can withstand temperatures below 20 degrees F. better than ponderosa pine seedlings. Consequently, conversion of lodgepole pine to ponderosa pine stands in frost pocket areas is not advisable. PNW(605,606).

432. Rapid changes and diminishing opportunities to ensure development of Alaska's resources creates an urgency to implement research. A multidisciplinary research program between various State and Federal agencies and the University of Alaska has been proposed to meet the needs of a rapidly changing resource development technology. PNW(615,628).

433. Development of an ecologically defined, habitat type classification for the forest vegetation of the Northern Rocky Mountains has provided land managers in this region with the means for describing the landscape by units of generally equivalent environment for tree growth. To visit and classify the habitat types on all parts of a large forest ownership, however, would require a great deal of field work and time. Criteria for interpretative mapping were developed using observed relationships between habitat type occurrence and topographic variables. Knowledge of these relationships allows large tracts, such as an entire National Forest, to be mapped interpretatively during regular timber inventories at little additional cost by sampling only a small part of the area. INT(608).

434. Many forest regeneration problems can be identified more precisely or even solved through the use of a classification system based on ecological relationships. One method currently used in the Western United States consists of stratifying land units into habitat types, which may be defined as units of land having a narrow range of environmental variations. Since many facets of the regeneration process are related to habitat types, including choice of silvicultural systems and species, site preparation techniques, and seed collection practices, the classification system is a useful tool for forest managers in developing regeneration guidelines. INT(635,639).

435. Mice have frequently been named as causing the death of newly germinated Engelmann spruce seedlings. However, recent findings in Colorado showed that 28 percent of the trees that died on an experimental area were killed by birds (grey-headed juncos) clipping the succulent stems of young seedlings. Consequently, normal rodent control measures often initiated solely on the basis of clipping evidence may be of little or no value. RM(633,634).

436. Attempts to encourage yellow birch, a high-value species, in northern hardwood stands have often failed. One reason for this is that sugar maple seedlings produce a toxic substance which inhibits the growth of yellow birch. Thus, sugar maple must be either discouraged or removed from stands intended for yellow birch, or sites without appreciable numbers of sugar maple must be chosen for birch production. NC(642).

437. The reaction of individual plants to gamma radiation has been studied in detail, but less is known about the effect of such radiation on an entire forest community which is modified by various environmental stresses. A technique using relationships between chromosomes and radiosensitivity has been developed in Wisconsin that will predict how a natural northern forest will respond to continuous gamma radiation over an entire growing season. Conifers will be eliminated at low radiation levels, while sedges appear to be most resistant to radiation. NC(645).

438. There is considerable interest in information concerning mychorrhizae but this information is widely scattered among many journals and books. A publication is now available which includes a complete listing of world literature on mycorrhizae. It contains 3200 references through most of 1973. This bibliography will be especially valuable to scientists and scholars working with limited library facilities. NE(611,612,613).

439. Little information is available concerning structure and succession of virgin forest stands in northeastern United States. Study of an 18-hectare northern hardwood stand in the Bowl Research Natural Area in New Hampshire indicated that species composition is restricted for the most part to beech, yellow birch, sugar maple, red spruce, balsam fir, striped maple, mountain maple, and hobblebush. The stand is characterized by large tree sizes and a well-developed J-shaped diameter distribution. The quantitative results are especially useful for developing alternative management strategies for northern hardwoods. NE(626).

440. The lack of reproduction of Allegheny hardwood trees following recent forest cutting is puzzling, since the current cuttings are similar to those that produced the excellent stands present today. A search of historical records on the forests of northwestern Pennsylvania suggests that two major changes have occurred to account for this problem: a much larger deer herd now exists and its feeding destroys reproduction; and as a result of their overmature condition and prior history of partial cutting today's stands lack the seedling understory present in the original forests. This information provides a useful insight into the regeneration problem for both foresters and laymen. NE(627,641).

441. Swamp tupelo and water tupelo are important species of the southeastern hardwood swamp forest. Research in South Carolina showed that under flooded conditions tupelos develop roots which have a high rate of anaerobic respiration and develop stem lenticels which absorb oxygen for transport to the roots. Both tupelos grow poorest in stagnant water. Management to provide a moving water regime should be considered a major factor for regeneration and rapid growth of these swamp species. SE(614,617).

442. Knowledge concerning the physiological and morphological bases for species adaptibility to bottomland soil moisture conditions is very limited. Flooding experiments in Georgia showed that height growth and root adaptations of

yellow-poplar, sycamore, green ash, sweetgum, and water tupelo were correlated with flood tolerance. All species except yellow-poplar could be spatially separated along a relative flood tolerance scale by the presence or absence of one or more root adaptations. These results suggest that the degree of root adaptability to flooding can have practical application in hardwood tree improvement programs. SE(601,616,644).

443. The disastrous floods of 1973 in the Mississippi River Valley caused concern among property owners, environmentalists, and resource managers about possible adverse effects of high water on forests. Studies and observations of flooding indicate that effects will depend on species and age of trees, depth and duration of flooding, and chemical characteristics of the soil. Spring flooding has improved growth of dominant, vigorous hardwoods. However, in areas where silt and sand deposits are 3 or more inches in depth and in depressions where water does not leave promptly, tree mortality may occur up to four years after flooding. Pines and many hardwood species in uplands are not tolerant to flooding and only a few weeks of high water during the growing season may cause severe mortality. SO(602,603).

444. In 1969 senna seymeria (*Seymeria cassioides*) was discovered as a parasite on the roots of southern pines. The parasite is most abundant in the Gulf and Atlantic flatwoods but does occur throughout the South. Where it threatens pines and the trees are large enough to survive fire, prescribed burning (after seeds germinate in the spring but before flowers appear) will kill this annual parasite. SO(610).

445. Direct-seeding yellow-poplar is a useful regeneration option, especially where steep slopes, rocky soils, or heavy logging slash make planting difficult. Exposed seed generally yields fair stocking, however, the role of seed-eating animals is unknown. On the Cumberland Plateau in Tennessee extensive depredations occurred in three successive years to unprotected seeds in trials at 10 widely dispersed locations. Seedspot protection tripled seedling establishment, with a corresponding increase in seedspot stockings. SO(637,638).

446. Most of the neotropical nations of the western hemisphere are mapped according to the Holdridge system of ecological life zones. To allow comparability with these areas, Puerto Rico and the U. S. Virgin Islands were mapped according to this same system. Six life zones were identified on the islands. Similar zones occur in South and Central America. Research done on the islands should be directly applicable to counterpart areas in South and Central America and conversely, successful practices there should be applicable in corresponding life zones on the islands. ITF(609).

447. A great deal of difficulty has been encountered in delimiting *Betula tortuosa tortuosa* as a separate species within the *Betula pubescens* group in northern Europe. A PL-480 funded project in Finland studies both experimental and natural populations of *B. tortuosa* and found certain morphological characters and features of growth which distinguish it from the southern provenances of *B. pubescens*. This investigation also provides strong evidence that hybridization and introgression have been the principal factors in the process of separation of *B. tortuosa* from the *B. pubescens* complex. WO:TMR(643).

448. Flooding with associated sedimentation and warmer waters, causes thaw in Alaskan taiga permafrost. After fire, thawing increases as much as 160 percent and may reach depths of one meter in the first 15 years after fire. There is a return to preburn levels in about 50 years. This sensitivity of permafrost situations to disturbance means that changes affecting environmental factors must be very carefully planned. PNW(527).

449. The taiga of Alaska consists of a vegetation mosaic resulting primarily from past wildfires. Today, both lightning- and man-caused wildfires burn an average of 400,000 hectares annually, creating vast areas of successional ecosystems. One of the important influences of fire in the taiga ecosystem is its effect on permafrost and the soil nutrient cycle. Some wildlife species, such as moose and snowshoe hare, depend upon fire and its resultant successional plant communities, whereas fire may have deleterious effects on caribou winter range. Fire has always been a part of the Alaskan taiga ecosystem: if it is totally excluded from the environment, some major ecological changes will result. Fire-suppression alternatives and the potential for fire management need to be developed. PNW(112,528).

L. Remote Sensing Methods

450. Spectral reflectance data must be collected on the ground to determine how solar and atmospheric measurement affect spectral reflectance data collected by the ERTS-1 satellite. For example, spectral radiance data collected from towers over healthy and dying ponderosa pines in the Black Hills of South Dakota were very different from scene radiances collected in two of the four bands from the ERTS-1. The satellite radiances were 35 percent and 20 percent higher in the green and red bands, respectively, than identical radiances found on the ground. No differences in scene radiance were found in the two reflective infrared bands. When these radiance differences are known for each band, improvements in pattern recognition by computer processing of ERTS tapes are possible and make automatic classification and mapping from multispectral scanner data a useful tool in identifying natural resources for land use planning. PSW(337).

451. The negatives of Earth Resouces Technology Satellite images furnished by NASA are too dense and unsuitable for making usable enlargements. A "System ASA Rating" was developed by testing and selecting combinations of film, light sources, and developer. The method can be used in relatively small darkrooms without expensive equipment. With special darkroom techniques uniformly good prints and enlargements can be produced for use in the field and office. PSW(335).

452. Methods of obtaining up-to-date information on land-use characteristics for forest planners might be improved by automatic interpretation techniques if the costs are feasible and high classification accuracy can be maintained. A computer classification map for one 42-square-kilometer (16-square-mile) test site in west Georgia was compared with a map made by photointerpretation and ground checks and revealed an overall accuracy of 61 percent. Accuracies ranged from 15 percent to 90 percent for all eight land-use classes considered. Automatic data processing of airborne multispectral scanner imagery is a significant advance in preparation of land-use classification maps. PSW(336).

M. Weather Modification and Weather Effects

453. Sea breeze fronts occur in coastal Georgia on about one-third of the days during the spring season. They advance at speeds from 0.9 to 10.0 m.p.h. Winds generally shift from westerly or southwesterly to southerly or southeasterly upon passage of the front, and wind speeds increase by 4 to 5 m.p.h. Converging winds in the vicinity of the sea breeze front can produce updraft speeds of more than 5 m.p.h. at altitudes of 1,000 feet above the ground. This study provides operational guidelines for assessing the impact of the sea breeze front on fire in coastal regions. SE(544).

454. The occurrence of heavy fog in coastal Georgia during the months of October, November, and December was related to relative humidity, wind speed and direction, pressure gradient, and general synoptic weather map types. Over 90 percent of all heavy fogs occurred within specific criteria or ranges of the above variables, and if the specified conditions occurred, heavy fog was observed approximately 55 percent of the time. Since the factors of fog formation and smoke concentration are similar, results from this study can be used to evaluate the potential of the atmosphere to locally concentrate smoke. SE(539).

455. Analysis of fire danger variables indicated that time of maximum fire danger occurs at about 1600 EST, but was not significantly different from the 1300 EST observation. There are winter and summer seasonal differences in fire danger in southeast Georgia. Most variables undergo change as frontal systems approach and pass an observing station. Statistical distribution descriptors were calculated for seasonal hourly averages. Stations were compared statistically by seasons and time of observation for all variables except rate of spread. This research provides a basis for delineating and comparing fire danger zones. SE(541).

456. The raw data from a network of meteorological stations were analyzed and found to approximate an Ornstein-Uhlenbeck stochastic process. From this analysis a crude filter was constructed that eliminated gross errors such as a temperature value that misses its leading digit. A linear digital filtering technique further smoothes the partially corrected data. This procedure provides a method for rapid machine editing of meteorological data that contain errors due to instrumentation or transmission. SE(533).

457. Researchers in meteorology and other physical sciences are frequently handicapped by lack of relevant statistical prodedures. Basic research on the properties of the normal distribution has resulted in tests for normality for sample sizes greater than 75. Properties of the shape and scale parameters of the Gamma distribution have been described and applied to rainfall data. Results from this research are being applied to fire problems and are widely used by the larger scientific community. SE(531,532,542,543).

458. Weather was a determining factor in the spread of the Sundance Fire in northern Idaho in September of 1967. A prolonged dry period, persistent high temperature, low humidities, and sustained strong winds produced a rapidly moving fire that engulfed more than 50,000 acres in a 9-hour period. The major weather factor, strong winds, was an atmospheric feature of large scale that could be tracked on weather charts as a predictable event. This detailed report represents a valuable source of meteorological information for research personnel, fire behavior specialists, and fire-weather forecasters. INT(534).

459. A summary of 4 years of data for the subarctic Bonanza Creek Experimental Forest located near Fairbanks showed that temperature varied significantly with elevation. Analyses further showed that Fairbanks mean monthly temperatures were higher than those at Nenana or at Bonanza Creek. Managers should be cautious about applying climatic data from one area to a distant area, even though the site may appear similar. INT(530).

460. Installation of special purpose instrument shelters can alleviate overcrowding in the thermometer shelter. Data comparability between stations is enhanced if uniform standards are adhered to. Overcrowding of the standard weather instrument shelter can lead to inaccurate measurements due to restricted air flow. Proper allocation of space and the use of a special purpose shelter in conjunction with the thermometer shelter will prevent this situation. INT(535).

461. Many western fire-weather stations are located where a standard ground cover of grass is impossible to maintain. A bed of small gravel or of coniferous needles can provide an acceptable alternative. Data comparability can be insured if an acceptable alternative to the standard ground cover is employed. INT(536).

462. A search of existing records showed that five wildfires burned more than 1,600 hectares of tundra on Alaska's Arctic Slope since 1969. Analysis of climatological records indicates that environmental conditions suitable for lightning, ignition, and burning occur on the average of 30 days each year. Man's increased activity in this area increases the probability of future fire occurrence. INT(529).

463. Intensive studies of fire weather and oxidant behavior are going on in southern California. Hourly means of surface temperature, dewpoint, wind components, and oxidant on southern California mountain sections show observable differences between the classes of days. A system was developed that can be used to predict the classification of a day in the San Bernardino Mountain area of southern California. Given the class of day, the time-sections can be used as a guide to forecast the temperature, dewpoint, wind speed, and wind direction, and oxidant concentrations throughout the day at any place on the mountain slope. This information will be very useful to fire managers in planning fire manning and control strategies. PSW(540).

464. The climates of Arizona and New Mexico were analyzed from the standpoint of forest and range fire behavior. Climatological elements of temperature and humidity were used to define the mean equilibrium moisture content during the season of high fire danger. Phenological stages of the lesser herbaceous vegetation were taken as integrators of available moisture, and were used to evaluate the moisture content of the fine fuel complex, which influences fire behavior. Climatological boundaries were primarily defined by marked transition in the equilibrium moisture content field. The time-space domain of the fine fuel moisture complex was used as a secondary delineator of boundaries. These applied climatological techniques are now operationally used by fire control and weather agencies in the western United States. RM(537).

465. One of the problems with fire danger rating systems is the proper consideration of quantity and duration of rainfall. Precipitation-hours per unit time and nationwide patterns of mean precipitation-hours per month and precipitation-day have been tabulated and mapped. These maps may be used as climatological translators of precipitation amount to duration of precipitation when using the National Fire Danger Rating System. NC(538).

II. IMPROVING UTILIZATION AND EXTENDING WOOD SUPPLIES

A. Intensive Culture Methods

1. Site evaluation and soil improvement

466. Before fertilization can be effectively used to increase tree growth in the Pacific Northwest, growth responses must be related to a broad range of soils, sites, and fertilizer regimes. In tests, on a poor site in Washington, application of 140 pounds of nitrogen per acre increased gross wood volume in a Douglas-fir stand by 73 cubic feet per acre per year for 7 years, whereas 420 pounds of nitrogen increased growth by 145 cubic feet per acre per year. Nitrogen fertilization also increased ponderosa pine volume growth by 3 to 67 percent over a 4-year period on four sites in Oregon. Continued research efforts to develop prescription fertilization treatments will provide the forest manager with an important silvicultural tool for increasing wood production. PNW(649,654).

467. Since conventional methods to determine productivity of land for growing Engelmann spruce in the central Rocky Mountains rely on tree height and age measurements, procedures for determining growth capability on cleared land have not been available. Productivity on such lands in Colorado and Wyoming can now be determined using an index based on soil and topography. With this information land managers can efficiently identify and intensify management practices where timber production may have the greatest potential. RM(655).

468. The North Central Region of the United States varies greatly in geology, soil, climate, and forest conditions. A bibliography has been developed of the varied and voluminous forest soils literature of the region to assist resource managers in land-use decisions. NC(647).

469. Black walnut can be grown on a variety of soils, but intensive cultural practices are not practical on sites that seriously limit growth rate. On bottomland sites in southern Illinois, 25-year-old walnut trees averaged 17 feet taller and 2.5 inches larger in diameter on deep soils (gravel layer deeper than 40 inches) than on shallow soils (less than 40 inches to gravel). Careful site selection could mean a 40 percent reduction in time required for black walnut to reach merchantable size. NC(652).

470. There is little published information on the availability or production problems of nursery grown black walnut seedlings. A survey of 25 States growing black walnut planting stock showed that shipments of black walnut seedlings increased from about 729,000 seedlings in 1963 to more than 2.7 million seedlings in 1971. The most important problems reported by nurserymen in growing walnut seedlings included irregular seed supplies, root rot, and poor seed germination. Preliminary findings from research in progress will assist nurserymen in increasing walnut seedling production. NC(650,656).

471. Collection of quantitative samples of some soil fauna, e. g., ants and spiders, is difficult due to their rapid movement. A method of applying CO2 from a fire extinguisher to the sampling frame was devised in South Carolina. Animals were immobilized for about 30 seconds and during this time, the sample could be lifted and placed in a plastic bag. The procedure enables one to sample fast-moving arthropods with confidence and improves estimates of organic decomposition. SE(648).

472. Release of nutrients for tree growth is often limited by slow decomposition of organic matter in the forest floor and mineral soil. A study of three soils in the North Carolina Piedmont showed that the supply of inorganic nutrients to microorganisms is an important factor in organic matter decomposition. Vegetative cover and soil type do not greatly alter this process. Results indicate that it is possible to manipulate the forest floor to accelerate nutrient cycling and tree growth. SE(651).

473. Prescribed burning of forests is a standard practice in the South but little is known about its influence on fauna in the forest floor and soil. In a South Carolina loblolly pine stand, prescribed burning drastically reduced the faunal populations when the floor was burned annually. There was no significant difference between nonburned areas and periodically (every 5 to 8 years) burned ones 43 months after a burn. If fire occurs at 5 to 8 year intervals and only the surface of the floor is burned, no lasting damage is done to the fauna. SE(653).

474. Southern pines are growing on many thousands of acres of land too wet to produce merchantable yields. Growth of slach pine on a wet sandy flat (SI50.. 50 feet) in northwest Florida was recorded for 10 years following construction of drainage ditches. Tree growth during this period was increased to that expected for a site 80 to 85. Land managers can greatly improve the growth and value of established stands by judicious drainage of wetlands. SE(657).

475. Large-scale planting programs in the South are often hampered by the shortness of the planting season. Studies in Mississippi show that cuttings of sycamore and cottonwood can be planted successfully in wet soil from October until budbreak in the spring. Sycamore seedlings can be planted in wet soil throughout the year. Foresters can use this information to expand planting programs for these two important southern hardwood species. SO(646).

476. Accumulation of fertilizer salt on stems of yellow birch seedlings results in the development of stem lesions that allow the entrance of microorganisms. Maintaining a high relative humidity in the greenhouse limits evaporation from pots and results in less salt accumulation on the stems and fewer lesions. This should effectively reduce the hazard of stem lesions of yellow birch seedlings grown under laboratory conditions for research purposes. NE(459).

2. Artificial regeneration

477. Jackrabbits generally have little effect on tree crops, except during forest regeneration periods. In a south-central Oregon plantation, blacktailed jackrabbits clipped the main stem of 43 percent of ponderosa pine seedlings, causing 3

times as many deaths among clipped as among unclipped seedlings during the first 4 years after planting. The reduction in height growth and overall tree size caused by clipping increases the length of time trees are susceptible to further damage, especially by pocket gophers. Land managers should be aware that high jackrabbit populations may result in the failure of ponderosa pine plantings. PNW(663).

478. Western nurserymen have difficulty producing conifer seedlings of uniform size because seeding machines provide inadequate control of sowing rate and subsequent bed density. Research in Oregon showed that more uniform sowing rates can be attained by sorting seed into size classes before drilling. Medium-and large-sized ponderosa pine seeds (0.17 to 0.20 in. and 0.20- in. diameter, respectively) drill more evenly than those in the smallest size class. By sizing seed before sowing, nurserymen should obtain more uniform seedling size and more even seedbed density. PNW(664).

479. Redstem ceanothus is a native shrub in the northwestern United States, and although considered a good game forage species, it is seldom used in revegetation because of strong seed dormancy. Studies in Oregon show that dormancy can be broken by immersing the seed in water for 10 minutes at 85oC and sowing immediately during the late fall rainy season. Thus, new burns and cutover areas can quickly be revegetated and allow use of the land for production of both wildlife and timber. PNW(666,673,679,680).

480. Commercially available seed-cleaning equipment is often unsatisfactory for use with small lots of forest tree seed. Researchers at the Forestry Sciences Laboratory at Corvallis, Oregon, recently designed a convenient, compact, gentle seed-cleaning apparatus combining the features of two commercial products and readily available construction materials. To date, seed lots of many coniferous species have been processed to yield seed that is 98-99 percent sound for small research projects. PNW(691).

481. The optimum spacing at which to plant *Eucalyptus saligna* in Hawaii with sawtimber as the final crop is not known. Saligna eucalyptus trees, planted in 1961 at spacings ranging from 8 by 8 to 14 by 14 feet, have grown rapidly in height and diameter. After 10 years, trees in all spacings averaged more than 90 feet tall. Average diameter ranged from 7.6 inches in the 8-foot spacings to 10.6 inches in the 14-foot spacing. Wide spacings appear to be better than narrow spacings for growing sawtimber. PSW(689).

482. Both natural and artificial regeneration of ponderosa pine in the northern Rocky Mountain-Intermountain Region have been sporadic and unpredictable. Research showed that proper site preparation and careful handling of planting stock were the essential ingredients for any planting program. Conditions for successful natural regeneration depend upon a combination of abundant seed supply and minimum competing vegetation. Using this information, guides were developed which will help forest managers determine the most reasonable regeneration methods to use in various habitat types to meet management objectives. INT(665).

483. Although spring is generally the preferred planting season for most forest trees, forest managers may wish to defer planting until fall because of easier access and the need to lengthen the time available for extensive reforestation projects. Recent studies in Idaho, show that fall planting of Douglas-fir, Engelmann spruce, grand fir, and western larch may be satisfactory. However, because of the variability inherent in fall planting, care must be exercised regarding choice of species, planting date, and aspect so that funds and available manpower are used most effectively. INT(678).

484. Reserve food in plants, mostly sugars and related carbohydrates, are necessary for growth and development. Studies with Engelmann spruce in Colorado showed that 3-year-old planted seedlings had low survival rates when reserves were low, but satisfactory survival was obtained at higher concentrations. Results indicate that carbohydrate concentrations below a certain, but as yet undetermined, level adversely affect survival. Cultural practices in the nursery should be directed at maintaining high reserve food concentrations. RM(674).

485. The primary cause of death in Engelmann spruce plantations in the central Rocky Mountains has been attributed to solarization. Solarization is the result of intense light which inhibits photosynthesis and may cause the death of trees planted at high altitudes. A paper summarizing high altitude research shows that solarization can be eliminated by shading newly planted Engelmann spruce. Young trees should be planted only in acceptable microsites on the north and east sides of logs, stumps, slash, or rocks. RM(675).

486. Recognition of the earliest time that ponderosa pine cones can be harvested from standing trees is important since the collection period is relatively short. When more than half of the cones in a sample from several trees will float in water, cones in that vicinity should yield a satisfactory number of viable seeds. Cones should be frequently checked after mid-August, since ripening proceeds rapidly thereafter. Using these guidelines for collecting cones from trees of superior growth and form will enable foresters in the Black Hills of South Dakota and Wyoming to efficiently obtain high quality seed. RM(683,684).

487. Although plastic greenhouses erected over tree nursery beds have generally proven successful in northern Europe as a means of increasing seedling growth by extending the normal growing season, similar techniques in Michigan yielded mixed results. Germination and seedling survival of jack and red pines was increased by 300 percent over that in uncovered beds, whereas no significant differences were recorded for white spruce and yellow birch. Similarly, significant shoot weight differences of several hundred percent were recorded only for red pine and spruce. The techniques appear promising for enhancing nursery production in regions having short growing seasons. NC(672,676).

488. Development of improved techniques for establishing successful hardwood plantations has helped stimulate more demand for hardwood seedlings. Hardwood seedlings are somewhat more difficult to grow than conifers, because they are more specific in their growth requirements. Special attention must be given to soil fertility, seed source, seed collection and handling, and seedbed care. In order to provide the high quality hardwood seedlings demanded, nurserymen must continually keep abreast with research progress and incorporate new results into practice. NC(690).

489. An automatic mist system to water seedlings and rooted cuttings must be reliable if it is to be used in greenhouses that are not manned every day. In New Hampshire a reliable system has been devised using inexpensive materials that can be easily obtained. The unit is particularly useful in temporary greenhouses where large investments are undesirable. NE(682).

490. Since mechanical site preparation is a costly part of plantation establishment, land managers need to know how varying levels of site disturbance affect survival and growth. Site preparation treatments resulted in increased growth of typical and South Florida varieties of slash pine in the flatwoods of South Florida. Growth increase was related to

degree of disturbance or reduction in competing vegetation. The results will aid managers in determining whether wood production increases in various species from site preparations should occur. SE(667,681).

491. Most forest tree species cannot be depended on to produce a good seed crop every year and seed should be stored as a hedge against crop failure. New methods for storing seeds for 2 1/2 years or longer have recently been developed for cherrybark, Shumard, and water oaks and water tupelo; four species that previously could not be held longer than one winter. Storage in 4-mil. thick polyethylene bags at about 38oF was suitable for all four species, but optimum moisture content was not the same and must be adjusted to meet the individual requirements of each species. These prescriptions will enable nurserymen producing seedlings for planting in the lower Mississippi Valley and elsewhere to maintain viability of these seeds for several years. SO(658,660).

492. Adequate information on growth and maturation of fruits and seeds of southern hardwoods has been lacking, but recent studies are filling in some of the gaps in scientific knowledge. Three years' research in central Mississippi confirms that green ash seeds are physiologically mature by mid-October, but moisture content is still too high to allow satisfactory storage. Seed collecting should be delayed until seed color changes to yellow or brown, usually in early November. These findings will assist collectors in gathering only high quality green ash seeds. SO(659,661).

493. Conversion from low-value hardwood stands to pines on west Gulf Coastal Plain sites can be accomplished by either planting or direct seeding. At age 9 years, planted trees were taller than direct-seeded ones for both loblolly and slash pine in a Louisiana study. The differences in height, about one year's growth, was attributed to their differences in age from seed. Although direct seeding is less expensive than planting, planting can be expected to shorten a rotation by one year. SO(668,669).

494. The difficulty in removing loblolly cones from trees makes cone and seed collection slow and expensive. Several chemicals that induce abscission of fruits failed to improve cone drop in a Louisiana study. Additional research demonstrated that pine cones lack an abscission layer. Chemical assistance for cone harvesting does not appear feasible. SO(670).

495. Mechanical tree shakers can greatly facilitate the harvest of slash pine cones. When 31-year-old slash pines were shaken with a Gould Vibra-shock tree shaker in a Louisiana trial, 66 percent of the mature cones were harvested with an average loss of only 4 twigs and one conelet per tree. Counts of cones and tree growth during each of the 4 years following shaking showed no difference between trees that were shaken and the controls. Results provide conclusive evidence that the shaking of slash pine trees by trained operators does not harm future cone production, tree growth, or vigor. SO(671).

496. In central Tennessee, planting is the only certain way to reproduce northern red oak promptly after harvest cutting or to upgrade depleted stands. Studies on the Cumberland Plateau near Sewanee, Tennessee, show that northern red oak can be planted readily on clearcut sites using conventional bar-slit methods. Seedlings can be top clipped and root pruned to facilitate handling and planting without impairing survival or growth rates. SO(677).

497. Measurements of respiration and chemical makeup can indicate changes taking place within dormant seeds prior to germination and in turn help to define the most suitable seed storage environment. But these measurements are difficult to make for large seeds such as oak acorns because the surrounding storage tissue masks changes taking place within the developing embryo. Researchers in Mississippi have found that cutting a cylinder of tissue (containing the embryo) from the center of water oak acorns for use in physiological analyses provides much more accurate information than using the entire acorn. Use of this technique will expedite development of improved techniques for breaking seed dormancy and inducing germination. SO(686,687,688).

498. Lack of uniform growth in container-grown seedlings makes it difficult to organize container nurseries for mass production. A study with *Pinus caribaea* in Puerto Rico showed that 39 percent of the variation in seedling height growth could be explained by differences in germination date alone. More uniform growth could be obtained by planting all containers in one area with seed that has germinated at approximately the same time. ITF(685).

499. Many nurserymen are unaware of the beneficial roles played by fungi infecting the feeder roots of nursery seedlings. A detailed description of how mycorrhizae contribute to the growth and survival of forest trees has been presented to tree nurserymen along with details of new research discoveries in the practical application of mycorrhizae. This publication has resulted in significant advancement in the practical application of mycorrhizae in forestation. SE(460).

500. Weed control is a continual problem in southern forest tree nurseries. The herbicide, terbacil, was tested to determine its effectiveness in controlling the most troublesome weed species. Terbacil eradicated 97 to 98 percent of the purple nutsedge plants and tubers in soil when applied as a soil drench at 4, 8, and 16 pounds per acre. Soil residues were toxic to soybeans, slash pines, and loblolly pines one year after treatment, toxic to soybeans 2 years after treatment, and nontoxic to soybeans 3 years after treatment. Although most nutsedge propagules were eradicated with applications of 4 pounds of terbacil, toxic soil residues render the treated area not usable for planting soybeans and possibly loblolly or slash pines for up to 3 years. SE(113,461).

3. Stand improvement

501. Lack of growth and yield information for sapling stands in the Pacific Northwest ponderosa pine region hinders decisions affecting forest management. Study results in Oregon show that stands in which understory vegetation was removed and saplings were thinned to 125 trees per acre produced 3 times more wood than the old-growth, uncut forest. Furthermore, the yearly volume increment was continually rising so that potential wood production in thinned stands could reach 5 or 6 times that of unthinned stands. With such growth potential management decisions may favor leaving saplings rather than clearcutting and planting, thus saving up to 10 years of growth that would otherwise be lost. PNW(692).

502. Wind damage can be severe in stands of overmature white and red fir bordering clearcuts in northeastern California. During a 6-year study, 77 percent of the loss in volume was due to wind, and about 20 percent was attributed to insect activity. Criteria for evaluating wind risk were identified and summarized, and now provide land managers with guidelines for selecting white and red fir trees which cannot be safely left standing near clearcuttings. PSW(696).

503. A significant percentage of pole-sized Australian toon and tropical ash growing on the island of Hawaii are cull. In

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trial plots, stumps of both species sprouted vigorously resulting in a high percentage of straight well-formed stems—88 percent for Australian toon and 82 percent for tropical ash. Coppicing from stumps of felled trees provides a method of converting cull stands to those stocked with "acceptable" trees. PSW(701,702).

504. Terminal shoots of young black walnut trees are often damaged by wind, frost, insects, and birds. Researchers in southern Illinois have developed a procedure for straightening deformed terminals that involves using one or more lateral shoots as supports for the most promising leader. Chances for producing high-quality trees for lumber and veneer can be increased by following simple procedures. NC(693).

505. Reliable data are not available to assess drift distance of herbicides applied by mistblowers. Tests on brushfields in the west Gulf Coastal Plain showed that soybean plants were not damaged beyond 510 feet when winds averaged 0 to 3 miles per hour with occasional gusts to 7 miles per hour, and when temperatures varied from 85o to 90oF. Test plants proved to be better indicators of drift than oil-sensitive cards. Under similar conditions, a 600-foot safety zone for sensitive crops should be adequate for herbicide spraying with tractor- and skidder-mounted mistblowers. SO(694,695).

506. Surfactants are routinely added to foliar sprays to increase herbicide effectiveness for controlling vegetation that competes with pines. Field and greenhouse tests in Louisiana showed that surfactants generally did not improve absorption or translocation of 2,4,5-T and dicamba by six hardwood species. Surfactants did increase 2,4,5-T absorption by loblolly pine. Surfactants may be an unnecessary expense in herbicide formulation and such additives should be used with caution where brush control is for pine release. SO(697).

507. Forest landowners in the South are concerned about slow diameter growth in dense, even-aged pines. In a Louisiana study of natural slash pine, stands which were strip thinned at age 3 grew as well as those selectively thinned. Thinnings should leave no more than 750 trees per acre. Mechanical strip thinning is much more rapid and less expensive than conventional selective thinning. SO(698).

508. Hardwood competition is a serious deterent to rapid growth of southern pines. Soil applied bromacil at 5 or 10 pounds per acre effectively killed post oak and blackjack oak. A 5-pound per acre soil application of picloram was more effective in killing hickory than was bromacil. Soil treatment with bromacil or picloram may be practical for hardwood control on tracts not suitable for machine operation because of size, location, or soil condition. SO(699,700).

4. Growth requirements

509. Geneticists and tree breeders who have only a limited number of plants to test need to know whether it is more efficient to test them at one location under different conditions of spacing and culture, or at several locations holding all other treatments constant. In a recent study of several families of pedigreed Douglas-fir seedlings in the Pacific Northwest, researchers found that all of them responded similarly when grown at several conventional spacings. They suggest that more useful information can be gained by conducting Douglas-fir genetics studies over a wide range of environmental conditions. PNW(720,722).

510. An optimum rooting medium must be selected to grow Douglas-fir seedlings in containers. Short-term trials in the Pacific Northwest have shown that seedlings grown for 30 days in shredded peat attained about twice the ovendry weight and twenty times the lateral root development as those grown in a nursery soil. Fast development of seedlings in peat permits more rapid evaluation of response in growth tests and speeds production of containerized Douglas-fir seedlings. PNW(724).

511. Young Douglas-fir trees found under shrub canopies form the new forest in cut-over areas, but growth is retarded by shade and competition for water. Aerial spraying of herbicides in Oregon released young Douglas-fir from varnishleaf ceanothus; their growth increased 1.7 to 2.5 times over that of trees on unsprayed areas during a 5-year period. Properly applied herbicidal treatments hasten succession from shrubs to timber types and increase the growth rate of crop trees. PNW(728).

512. Southwest Oregon has extensive commercial forests, yet little information exists for increasing tree growth. In 30-year-old Douglas-fir growing on a poor site, 4-year basal area growth of dominant trees was increased 57 percent by fertilizing with a combination of nitrogen, phosphorus, potassium and sulfur, 53 percent by thinning, and 94 percent by combining both treatments. For land managers this is direct evidence that growth of crop trees in this relatively dry area can be increased by fertilization and thinning. PNW(740).

513. Millions of containerized seedlings are being planted in the western United States but sufficient information is not yet available to fully evaluate performance after outplanting. Douglas-fir seedlings in small containers performed well under favorable conditions, but poorly on dry sites. This suggests that transplanted nursery stock, rather than containerzied seedlings, should be used on harsh sites. Such behavior is most likely drought related since research has shown that large Douglas-fir seedlings rapidly deplete available water in small pots. Field trials to compare performance between the two kinds of stock should be standardized to insure uniformity of such items as seed source, handling of stock, planting techniques, and planter variability. Comparative data will lead to the development of sound guidelines for planting potted seedlings. PNW(743,744,745).

514. If seed orchard managers and tree breeders are to be able to enhance flower and seed production, they must have accurate knowledge of the schedule on which flower buds develop and mature. Recent research in Oregon indicates that there may be several critical periods during which the course of Douglas-fir flower development may be influenced. In one case, shading of branches in May or June reduced the numbers of both male and female flower buds in the following year and thus depressed seed production a full 29 months after treatment. In contrast, small grafted seed orchard trees dug up and replanted the first of July produced an average of 23 cones the following year compared with near zero for corresponding unmoved trees. Tree moving or root pruning may be a useful tool to induce early flowering in Douglas-fir seed orchards. PNW(754,755).

515. The quality of wood fiber produced in a forest plantation has an important influence on the profitability of the plantation. In the central Sierra Nevada of California a high-elevation ponderosa pine plantation produced trees with fibers only 83 and 88 percent as long as those produced at low and middle elevations respectively. Tree diameters are larger and heights equal or greater at the high-elevation planting. Forest managers wishing to produce wood of maximum fiber length should not establish ponderosa pine plantations at elevations above 5000 feet in the central Sierra Nevada. PSW(723,736).

516. Although Engelmann spruce is adapted to the cool environment associated with high elevations in the Central

Rocky Mountains, seedlings germinating late in the growing season are susceptible to sudden drops in temperature during late summer or early fall. Studies in Colorado reveal that seedlings undergo physiological changes at 10-12 weeks of age, enabling them to withstand temperatures as low as 15oF. These results will alert land managers to the importance of early sowing so that seedlings have time to develop cold resistance before the onset of winter. RM(742).

517. A Black Walnut Symposium held at Carbondale, Illinois, in August 1973 attracted over 300 participants to discuss recent research progress and recommendations for efficient use of walnut resources. Thirty papers on utilization and marketing, silviculture, tree improvement, nut culture and production, protection, and economics of black walnut were published as symposium proceedings. This report summarizes the state-of-the art of black walnut as a crop. NC(735,746,756,757).

518. Correct interpretation of data involving physiological processes in plants requires a thorough understanding of the anatomy of twigs and attached leaves. Using radioactive tracers and improved techniques for plant tissue preparation, scientists in the Lake States have described the complex vascular conducting system of developing cottonwood shoots and leaves. Their work led to the conclusion that anatomical development was a limiting factor in both photosynthesis and translocation. NC(730,731,735).

519. Fertilization has been recommended as a means of increasing growth of planted hardwood seedlings; however, surface applied nitrogen fertilizers can stimulate growth of competing vegetation to the extent that desired seedling growth may often be retarded. First- and second-year growth of yellow-poplar seedlings planted on an old-field site in central West Virginia were increased, and competing ground cover eliminated by broadcasting calcium cyanamide around the seedlings at rates corresponding to 400 and 500 pounds of nitrogen per acre. Seedling survival was not affected by calcium cyanamide. NE(706).

520. More intensive forest management will be necessary if we are to meet the projected demands for fine hardwoods. Research on black cherry in northwestern Pennsylvania shows that fertilization of seedlings with nitrogen and phosphorus can produce as much as 8 feet of terminal growth in a single year. Furthermore, response to fertilization varies markedly among black cherry genotypes. Thus, it appears likely that the intensive culture of black cherry based on fertilization of selected genotypes will permit large increases in yield as compared to current extensive cultural practices. NE(704).

521. Although forest fertilization has great potential for increasing growth rates and shortening rotations, research results to date are limited and widely scattered in the literature. Proceedings of a symposium sponsored by the Northeastern Forest Experiment Station bring together research results and current thinking of 33 eminent scientists on the benefits of fertilization in terms of timber, wildlife, water, and recreation management, as well as insect and disease control, in the northeastern United States and eastern Canada. NE(705,758).

522. For successful forest fertilization under intensive management, nutrient requirements of individual trees must be determined under controlled laboratory conditions. One such study conducted with paper birch in Pennsylvania indicated that a 3 to 4 percent nitrogen content in foliage was adequate for satisfactory seedling growth. This information on one of the many essential elements needed by plants contributes toward understanding the nutrient requirements of this important species. NE(713).

523. Rapid growth of sugar maple seedlings requires optimum soil moisture and fertility levels. In a New England study of 3-year-old potted sugar maple seedlings, shoot growth responded 29 percent more than root growth to additional water. Thus, high levels of soil moisture may lead to higher shoot:root ratio, and this may retard establishment of outplanted sugar maple seedlings. In contrast, fertilization did not stimulate seedling growth. NE(721).

524. Photosynthetic potential in pines depends largely on the amount and length of leaves and the spacing of needle fascicles among shoots. For red pine, the growing season in Michigan can be divided into three two-month periods; April-May, June-July, and August-September. Moderate drought during the middle period, a common occurrence throughout the range of red pine, results in two separate effects on foliage development the following year, one compensating for the other. In this Michigan study, the growth of watered trees was similar to that of check trees, suggesting that natural rainfall provided adequate moisture for relatively good growth. NE(726,729,747,761).

525. The benefit of intensive culture for tree growth has not been established on many soils. Total volume of 5-6 year-old slash pine planted on Florida sandhill sites that were subjected to various combinations of irrigation, N and P fertilization, and weed control was 76 to 330 percent greater than untreated trees. If a forest manager intends to increase slash pine growth on lakeland fine sandy soil it will be necessary to improve both the moisture and nutrient regimes of this soil. SE(708,709).

526. The potential of early pollen production for genetic testing in pines is often overlooked. A study in the Virginia Piedmont showed that male cones developed on Virginia pine trees just 18 months from seed. Early flowering may have resulted from an extended first-year growing season using special greenhouse-field techniques. Early intensive culture offers a means of reducing the interval required for seed to plantation establishment and pollen production in pines. SE(711,712).

527. Conversion of scrub hardwood stands to pine on Florida sandhills is usually unsuccessful unless the site is thoroughly prepared prior to planting. Pines survive and grow as well when sites are prepared with one pass of an 11-ton duplex brush chopper followed by a second pass with an 8-ton or 4.5-ton chopper as when an 11-ton chopper is used for both passes. This treatment will result in improved site preparation and a savings in time and operating cost. SE(718,719).

528. Forest fertilization has the potential for greatly increasing yields in some parts of the eastern United States. A summary paper presents fertilization results by region and species. Additional basic and applied research assessing the total biological impact of fertilization must be carried out before broadscale treatment can be considered economically and environmentally sound. SE(750).

529. Intensive culture of southern pines is necessary if the South is to meet future requirements for wood products. Twelve years of irrigating a slash pine plantation in north Florida raised the soil pH from 5.7 to 7.6 units; tree growth accelerated until pH exceeded 7.1 units. Covercropping with a nitrogen-fixing legume increased the soil nitrogen level an average of 142 ppm and increased tree growth. Results indicate that 1) covercropping may be a valuable cultural tool for southern pines and 2) the source and nutrient content of water must be closely examined before long-term irrigation is recommended for pine culture. SE(749).

530. Mechanical site preparation and planting alter the rooting and growth habits of slash pine. In the north Florida flatwoods, 5myear-old trees planted on beds had fewer long lateral roots but twice the root and shoot biomass as trees planted on level ground. Both hand and machine planting compress roots in a single plane which increases the potential for windthrow. Land managers should bed flatwood sites subjected to periodic flooding and only plant trees which have been root pruned at the nursery. SE(751).

531. A handbook has been developed in response to accelerated regional interest in planting sand pine on droughty southeastern soils. Research information on the distribution, wood properties, seed development, nursery practices, site characteristics, planting and management of two varieties of sand pine is synthesized. This will provide land managers from Florida to South Carolina with multiple use options and improved productivity techniques on dry sandhill areas. SE(759).

532. There are extensive areas in the southeastern Coastal Plain where soil phosphorus is deficient. Soil tests and foliar analyses were developed which show that if needle phosphorus (P) is below 0.10 percent or soil P is below 3 ppm, P fertilization will usually increase tree growth. Application of these guides will prevent P fertilization where it is not needed and increase timber production on phosphorus-deficient soils. SE(760).

533. Survival and growth of eastern cottonwood planted on abandoned fields in the Mississippi Delta are often poor. Several soil management techniques have been tested in attempts to rejuvenate these old fields and one of them, summer fallowing, has proved to be beneficial. Fallowed fields were disked four times during the summer prior to planting, and also treated with herbicides. In comparison with performance on untreated fields, fallowing increased the height of 2-year-old cottonwood by 5 feet (18 feet vs. 23 feet) and increased survival by 18 percent. As a result of this research, a large forest industry in western Mississippi is summer fallowing old fields on an operational scale. SO(710).

534. Standardized seed testing methods are necessary in order to allow quality comparisons to be made among seedlots of the same tree species. Recent tests made in Mississippi indicate that the commonly used alternating temperature regime of 20 and 30oC. is appropriate for American sycamore, a species for which no standard test had been recognized. For sweetgum, however, use of warmer temperatures, alternating between 30 and 40o, allowed completion of the tests in only 14 days instead of the customary 28. SO(707,714).

535. The relationship of pine flowering to environmental conditions is poorly understood. A study of longleaf pine in southern Alabama revealed that air temperature near staminate strobili is the major factor controlling their development rate. Flowering occurs when the degree-hours above 50oF (accumulated from January 1) exceeds 11,000 and before it reaches 16,000. Heat sum accumulation will indicate strobili development status and permit seed orchard managers and tree breeders to anticipate flowering dates. SO(715,716).

536. Water table depth is an important soil factor in successful establishment of cottonwood plantations in Mississippi. In a controlled study, a water table 2 feet from the soil surface increased growth by weight more than 100 percent over no water table (watered by rainfall only). The 2-foot depth was the critical level; above that, growth was restricted. A water table below 2 feet, but within the root zone, was beneficial to growth. This information will assist southern forest managers in the selection of bottomland sites that are suitable for cottonwood plantations. SO(717).

537. Knowledge of how trees respond to various combinations of nutrients is imperative to proper and effective forest fertilization. In a greenhouse study in Louisiana, application of nitrogen (N) or phosphorus (P) alone failed to stimulate slash pine growth on an imperfectly drained soil. However, a marked growth response occurred when the equivalent of 50 kg. of P and 168 kg. of N was applied per acre. These results suggest optimum N-P field fertilization rates for a broad range of heavy and imperfectly drained soils. SO(738).

538. The need to produce more wood on an increasingly limited area is leading to the more frequent use of intensive culture. Tree growth can be greatly increased, but the possibility of reduced quality in rapidly grown wood has caused concern. Fertilizing and cultivating plantations on infertile soils in southern Mississippi increased dry wood production of loblolly, slash, and longleaf up to 6, 7, and 16 times as much as in untreated plots of the same species; the tremendous gains in growth attained through intensive culture, however, were not accompanied by any decrease in wood quality. These results provide additional incentive for land managers to invest in intensive culture as one method of producing larger volumes of wood. SO(748).

539. Consistent, high production of seed in pine seed orchards and seed producing areas requires a thorough understanding of environmental factors influencing flowering. In Arkansas and Louisiana trials, female flowering of slash and loblolly pines were closely associated with rainfall in the preceding year. Other factors affecting flowering were (1) inherent tendency of trees to flower, (2) rate of annual fertilization, and (3) flower production two years earlier. These results suggest that maximum flowering may be assured by irrigation in spring and by annual fertilization, with fertilizer applications based on local soil conditions. SO(727,752).

540. Accurate answers must be obtained to the questions of where, when, how much, and what kinds of fertilizers are needed to maximize tree growth. In a status report on pine nutrition in the West Gulf Coastal Plain, it was concluded that future research should concentrate on (1) relating nitrogen and phosphorus fertilization to soil and site and (2) developing superior pines which are unusually responsive to fertilizers. This document will assist forest land managers in selecting soils or sites which will respond to supplemental nutrition. SO(753).

541. Recent studies in Israel have provided further proof that wood, as well as other plant tissue, is formed as a reaction by cells to stimuli which are produced in the leaves and move through the plants. The influence of young and mature leaves could, in some cases, be imitated by known plant hormones, and these effects could be related to the production of porous wood early in the growing season and denser fibrous wood later in the summer. The research, which was conducted under the auspices of the PL-480 program, has provided a number of new hypotheses essential for continuing basic studies in wood formation. WO:TMR(725).

542. Morphactin is a naturally occurring plant growth regulator with a mode of action that is not well understood. In India, a research team supported by the PL-480 program has found that morphactin impedes the movement within tree roots of another plant hormone, auxin. This action inhibits the development of new primary roots while stimulating the growth of secondary roots. This could lead to a practical method of promoting the development of a desirable fibrous root system on tree seedlings in the nursery to enhance their field survival. WO:TMR(732).

543. The mechanisms controlling seed dormancy are still not well understood. Scotch pine seeds were subjected to low temperature (3oC) and darkness for periods up to 30 days. This Polish PL-480 research project found that 20 day cold stratification resulted in over 80 percent seed germination in darkness and white or red light, with a concurrent increase in gibberellin. This is further evidence that the plant hormone gibberellin is closely associated with seed germination. WO:TMR(733).

544. Naturally occurring growth hormones by their very existence are assumed to be of importance to plant development, but their function is often poorly understood. Ferulic acid is one such compound that has been intensively studied in Poland with the support of the PL-480 program. Among other properties, it promotes water uptake by willow twig cuttings, and more important, the cuttings are strongly stimulated to take root. Ferulic acid may prove to be quite valuable to nurserymen and researchers as a treatment to induce rooting of woody plants. WO:TMR(739,741).

5. Growth and yield

545. What gains can be attained from initial thinnings that are delayed beyond the optimum time? A Douglas-fir stand in Washington which was thinned 4 times at 5-year intervals beginning at age 57 was estimated to have 5 percent greater total usable production than a similar unthinned stand at age 72. The primary gain from delayed thinning in Douglas-fir is an early harvest of part of the stand, largely at the expense of volume otherwise available for final harvest. PNW(772).

546. Within 2 decades, nearly all virgin stands of nonreserved coast redwood will be harvested, and according to studies in California, over half of the future crop trees in these areas will develop from stump sprouts. Thinning dense clumps of sprouts can concentrate growth on future crop trees so that size and wood volume is optimum; volumes of sprouts 5 years after thinning may increase by as much as one-third while diameters can more than double. PSW(764).

547. Management of white and red fir has been clouded by many observational reports over the last 30 years of the invariably slow growth rates of these species. Recent research in California by sampling and measurement techniques provides better growth statistics. Starting within 1 or 2 years after release from overstory competition, young fir trees showed tenfold increases in radial growth, and after 5 years at least fourfold increases in annual height growth. These findings have opened the way to future management of white and red fir by putting to rest much of the misinterpreted information in the technical literature on the growth rates of these tree species. PSW(767).

548. Dwarf mistletoes are so common on lodgepole and ponderosa pines that growth projections are often invalid unless growth losses from this parasite are included. A paper, written for timber managers and pathologists, provides instructions for data collection which can be applied to previously published procedures and computer programs for preparing tables on growth and simulating yield of mistletoe-infected forest stands. RM(769).

549. To successfully manage valuable hardwoods we must be able to estimate both the quantity and quality of veneer and high-grade saw logs that can be produced on lands differing in site quality. New site index curves for upland oaks can be used for estimating site quality. These same curves can be used to determine how contrasting tree height and diameter-growth patterns for good and poor sites are related to log quality. WO:TMR(765).

550. Growing aspen sprouts under short crop rotations and harvesting whole trees has recently gained popularity as a means of obtaining maximum wood-fiber yield. Since normal forest measurement techniques for estimating productivity are based on less intensive utilization, new methods for measuring stand development and productivity are needed. A study in Minnesota developed equations that provide unit area estimates of number of surviving stems, oven-dry total weight, and oven-dry wood weight for aspen up to 20 years of age. NC(770).

551. Thinning alters the growth of southern pines but it may not improve yields. Thinning two young shortleaf pine plantations to basal areas of 110 to 120 square feet at ages 14 to 22 years did not alter merchantable yields when compared with no thinning (125 to 200 square feet of basal area). Thinning to 70-90 square feet of basal area reduced yields by as much as 13 percent. This southern Indiana study shows that thinning cannot be expected to increase shortleaf pine yields prior to age 30. NC(771).

552. Utilization of the entire above-ground woody parts of trees appears promising as a means for increasing fiber supplies. Productivity studies in Oregon showed that total biomass (except leaves) of noncommercial timber stands of red alder reached a maximum of 240 metric tons (mt) per hectare by the age of 33 years. Net primary productivity during the years of maximum growth (between 10 and 15 years) averaged 26 mt per hectare per year. For best yields it is recommended that stands be harvested before the age of 20 years. NC(775).

553. Measurement data for hardwoods grown in plantations are almost nonexistent. Cubic-foot volumes, green weights, and dry weights have been developed for plantation-grown sycamore trees in Georgia ranging from 4 through 10 inches d.b.h. and 45 through 80 feet in total height. The tables and prediction equations will be used to estimate growth, yield, and biological potential of sycamore plantations in the South. SE(763).

554. Since slash pine is not native west of the Mississippi River, there are doubts about the applicability of published site-index curves in that region. New curves were derived from 538 data points in slash pine plantations on cutover sites in the West Gulf and are recommended for stands under 15 years old. These new curves will permit landowners to accurately project potential growth of planted slash pine as young as 5 years of age. SO(762).

555. Most site index curves for the major southern pines must be used graphically. Equations were developed to produce site index curves for loblolly, slash, shortleaf, and longleaf pine that can be subjected to electronic data processing. These equations are accurate to within plus or minus 2 percent of published heights from site index curves. These equations and regression coefficients will expedite growth and yield calculations. SO(766).

556. Tree growth cannot be accurately projected for shortleaf pine in the 5-million-acre Ouachita Mountain Province of Arkansas and Oklahoma. New site index curves have been developed which are adjusted for site quality. These curves are preferable to standard anamorphic curves for stands less than 40 years of age and will permit managers to make unbiased estimates of growth for all ages and site qualities. SO(768).

557. The variation in individual tree volume increases as trees increase in size. A statistical procedure has been developed which minimizes the effects of individual tree variance for young loblolly and shortleaf pines. This technique will

aid forest biometricians in fitting tree volume models for other species. SO(773).

558. In many areas where loblolly pine is planted in the west Gulf States, young trees become heavily infested by the Nantucket pine tip moth. Because no economical method of controlling the insect is available and genetically insect-resistant stock has not been developed, many foresters substitute slash pine (which is tip moth resistant) for loblolly pine. In large 30-year-old plantations near Bogalusa, Louisiana, loblolly pine was found to recover strongly and grow well after early tip moth infestation. Land managers can choose either slash or loblolly pine for planting, basing their decision on the soil and site requirements of the species selected. SO(774).

6. Forest measurements

559. Usual methods of remeasuring tree heights on permanent sample plots become more difficult and expensive as trees grow taller. A new method was developed in California using surveying techniques and electronic data processing. Permanently recorded coordinates and elevations of tree locations are used with angles to calculate the instrument location and elevation, instrument-to-tree distances, and total tree heights. This method can reduce the costs of tree height remeasurements. PSW(781).

560. Because of the increasing trend toward purchasing aspen wood by weight in Minnesota, there is a need for methods of determining sale units by weight rather than the traditional volume measurement. Weight yield equations were developed that provide unit area estimates of both green and dry weights for wood, bark, and branches to any height along the stem. Use of these equations will enable estimates of weight to be obtained more accurately and efficiently. NC(782).

561. The maximum age to which tree species may live in New England is not known but this information would be useful in selecting trees where longevity is needed. Ages were determined for the largest stems of several species of trees and shrubs found on a series of plots on Mount Washington, New Hampshire. Heart-leaved paper birch trees were found to live as long as 225 years, far older than originally suspected. This species would be suited to growing in urban or forest situations where great longevity is desirable. NE(776,779).

562. Accurate evaluation of forest productivity is essential for optimum land management. Height over age site curves for white pine in the Southern Appalachians and loblolly pine in the Coastal Plain of the Carolinas and Virginia are subject to substantial error due to sampling bias, curve shape, and improper use. Prediction of site index can be improved by using curves developed or verified by stem analysis or periodic remeasurement and using polymorphic site curves which allow shape of the curve to vary by site. SE(777,778,780).

7. Management planning

563. Quaking aspen is the most widely distributed tree species in North America and predominates on six million acres in the central Rocky Mountains. Knowledge of aspen and its related understory vegetation is essential for making management decisions on aspen-dominated lands. Researchers in Utah developed a mathematical model to simulate the successional change of aspen to climax conifer types in the absence of disturbance. The model consists of three main processes (growth, regeneration, and mortality) and five vegetational compartments (aspen, conifers, shrubs, perennial herbs, and annual herbs). The simulation is being used as a problem analysis to guide future multiple-use research and management in this important vegetation type. INT(783).

564. Forest management planning requires the capability to forecast the development of stands under different conditions (e.g. species composition, age, and vigor) and management prescriptions. A new computer program allows prognoses to be made for existing forest communities rather than hypothetical tree distributions which are used in most simulator programs. Applications of this stand development model will lead to better management of six important tree species in Idaho and Montana. INT(787).

565. Age at which trees are harvested and the intensity of cultural practices have a major influence on the volume of timber and the amount of money a forest stand may yield. Field tests to evaluate different stand treatments, however, are not only expensive and time consuming, but they may impose undesirable treatments on stands that will not disappear for some time. The effects of cutting systems and other management practices can now be simulated inexpensively on a computer for each set of alternatives. This provides a manager with information on annual and periodic costs, rate of monetary returns, and other statements related to volume or value. RM(784).

566. Social and economic factors affecting land management are changing so rapidly that new timber management plans may be needed annually, rather than at 10-year intervals. The need for rapid preparation of such plans with minimum manpower requirements is met by a computer program, TEVAP2, which analyzes inventory data and writes timber management plans. An associated program updates the inventory file of records from: (1) conventional sample plots, (2) compartment examinations, (3) current reports on thinnings and other changes, or (4) any combination of these sources. The procedures were tested for 2 years in South Dakota and Wyoming on the Black Hills National Forest. The data handling and computer time required to prepare a new plan of a million-acre working circle amounts to a total cost of about $500. RM(785).

567. Managers need methods for simulating responses of forests to various anticipated treatments so they can decide which treatments to field test and ultimately to apply. A study in Georgia demonstrates how new technology makes simulation useful in (1) derivation of production functions or system models, (2)searching for optimum management strategy, and (3) assessing departures from optimum if inputs are not closely controlled. A specific example shows that simulation of the dynamics of even-aged forest stands can assist a forester in assessing management regimes involving various timings and intensities of thinnings. SE(788).

8. Maple syrup production

568. Previous investigators attributed variation is sap and sugar yields among sugar maple trees to the relative size of the tree crown, but some studies indicated that the relationship was weak. Sampling of 180 trees in three sugarbushes in northern Vermont showed that no combination of the physical characteristics measured could be used consistently to predict sap-sugar concentration, sap-volume yield, or total sugar yield. This study points up the need for more basic research into the biological processes involved in maple sap production. NE(789).

569. Tapping sugar maples to extract sap causes damage and dieback to the extent that the taphole usually does not

close for three or more years. Twenty-one chemical and physical treatments designed to stimulate the growth of callus tissue surrounding tapholes were not successful. Three possible reasons for treatment failure suggest new approaches for future research on this problem. NE(790).

570. There has been inadequate information available for operators who wish to produce quality wood as well as the highest possible yield of sugar-rich sap from their sugarbushes. Stocking guides, inventory procedures, and cutting methods for sapling, pole timber, and small sawtimber stands are available in a new practical guide for the management of a sugarbush. In addition, a procedure is described for testing for sap sweetness in order to select trees for proper thinning. NE(791).

9. Naval stores

571. Many laborers in naval stores production have turned to other jobs because the cash return per man-day work was low. A pilot plant study in southern Georgia revealed that laborers were able to earn more than $30 per day working under either a rental or sharecropping wage system—if they received adequate supervision. Gum naval stores producers must provide better production supervision of their laborers if both producers and laborers are to continue to profit in the industry. SE(792).

572. Although the gum naval stores industry is much smaller than it was 10 years ago, opportunities exist for good production and good profits. There is adequate timber and the price of crude gum is at an alltime high of $60 per barrel. Research in commercial operations in Florida and Georgia has shown that with improved methods and good supervision gum production can be increased 33 percent without employing additional laborers. This research also indicates that with good productivity laborers can earn over $30 per 8-hour day of work. SE(793).

573. The current worldwide shortage of rosin has caused extremely high prices and prompted users to search for substitutes. Recent research in northern Florida has shown that treatment with the herbicides paraquat and diquat can induce lightwood formation (resin soaking) in slash and longleaf pines. This discovery offers a great opportunity to develop a new, efficient, and nonpolluting method of producing turpentine and rosin by extracting them from lightwood in existing stumpwood extraction plants and pulpmills. If only five percent of the pulpwood going to southern mills were treated to induce lightwood formation, it would furnish as much rosin and turpentine as is now produced by the entire naval stores industry. SE(794,795).

B. Breeding Improved Trees

1. Inherent variation

574. If poorly adapted seed sources are selected for use in reforestation, they may be subject to damage by extreme weather conditions. An unusual frost in the Willamette Valley of western Oregon in October 1969, emphasized this potential problem. Among young Douglas-fir seedlings originating in ten stands in western Washington and Oregon, about 71 percent of those from the stands farthest to the south suffered frost damage in contrast to only about 17 percent damage to seedlings of more northerly origin. Only Douglas-fir seedlings with inherent cold hardiness should be planted in frost pockets and similar high-risk sites. PNW(799).

575. The genetic superiority of many individual parent trees has been proved by field testing, but some of the tests were made at only a few locations. It is important to find out if seedlings produced by selected trees are suited to a wide range of sites or only a few. To investigate this problem, pedigreed Douglas-fir seedlings from two nearby stands in western Oregon were grown in both good and poor soils. There were considerable differences in height among families of seedlings from different parent trees and individual families showed consistent growth on both types of woil. Seedlings from verified superior parent trees can be relied upon for planting throughout local tree improvement zones. PNW(825).

576. Trees of the same species that originated in widely separated geographic zones are often found to grow at different rates. If breeders are to take maximum advantage of these differences, it is important to know their underlying physiological causes. Douglas-fir seedlings from western Montana or northeastern Washington when grown in a warm environment produce relatively more root than shoot growth in contrast to seedlings from western Oregon. It may be possible to select and breed Douglas-fir seedlings that are suited to quite specific site conditions. PNW(826).

577. Establishing forest plantations using genetically inferior seed can seriously reduce productivity. After 29 years in three test plantations in the central Sierra Nevada of California, the growth of ponderosa pine has been markedly influenced by the elevational origin of the seed. Mid-elevation seed sources produced trees that were tallest in low- and mid-elevation test sites. At the high-elevation plantation, trees of mid- and high-elevation origin grew equally tall. For planting up to 5000 feet elevation, the optimum seed collection zone lies between 2000 and 4000 feet on the west slope of the Sierra Nevada; seed sources above 5000 feet are presently recommended for planting at the same high altitudes. PSW(802,833).

578. The most serious pest of western white pine in the Northwest is white pine blister rust. Breeding for improved disease resistance appears to be the most promising method for control. A breeding program based on more than 20 years of intensive research has recently yielded very encouraging results. A group of more than 3000 second-generation-hybrid white pine seedlings, all bred from rust-resistant parents, showed 66 percent resistance to blister rust after 2 1/2 years exposure to infection in the nursery and 88 percent resistance after an additional 2 years exposure in field outplantings. In contrast, only 19 and 24 percent of control trees escaped infection. Orchards have been established that will produce rust-resistant seed sufficient to plant 15,000 to 20,000 acres of western white pine per year by about 1985. INT(798,813).

579. Reforestation efforts in the Southwest have been hampered because planted trees or seeds were not adapted to the site. Forested areas of Arizona and New Mexico have now been divided into zones in which plantation establishment will rely on seed collected only within the particular zone. Thus, costly errors in seeding or planting trees from unsuitable seed sources will be avoided. RM(822).

580. Scotch pine is favored as a Christmas tree throughout the Midwest, but because planting stock of desirable known genetic origin is often unavailable, many plantation trees are not marketable because of yellow foliage or poor form. Scotch pine trees originating from an area stretching from Spain to Siberia were tested for 9 years in eastern Nebraska. Only trees from Spain, southern France, and Turkey retained desirable dark green needles throughout the winter; they also grew at an appropriate rate for Christmas trees. Commercial quantities of seed have been obtained from Turkey and are being used to produce planting stock for the Nebraska tree distribution program. RM(821,827).

581. Past performance of red pine trees on older Nebraska farmsteads has indicated that this species might be desirable for environmental tree plantings, but there has been no information as to which seed source might be best. In an 11-year study in eastern Nebraska, red pines from certain locations in Wisconsin, Quebec, and lower Michigan have grown from 7 to 13 percent faster than the average of 50 other seedlots. Commercial quantities of seed from these specific stands will be obtained in order to provide the state tree distribution programs with improved red pine planting stock. RM(832).

582. A considerable expenditure in high-quality land and intensive culture is being made to establish new black walnut plantations. The use of the best available seed sources can help to justify this investment. In test plantations in eight midwestern States, walnut trees from as far as 200 miles south of the planting site have grown as large as or larger than trees from local or northerly souces. However, in the northernmost test plantation (southeastern Minnesota), survival was generally higher for trees from northern sources. With this additional information, new black walnut seed collection zones throughout its range have been delineated to guide nurserymen, researchers, and tree improvement specialists. NC(797).

583. Yellow birch is in high demand for sawtimber and veneer. This valuable hardwood species has considerable potential for genetic improvement. To assist tree improvement workers in planning research and action programs, a summary of yellow birch genetics has recently been published. Taxonomy, distribution, and natural reproduction are described with special emphasis on controlled crossing, genetic variation, and practical improvement programs. NC(800).

584. As tree improvement work proceeds from research into practice, it is necessary to learn the patterns of genetic variability within each species. This sort of variation has been intensively studied in a Wisconsin plantation of yellow birch seedlings produced by 137 parent trees from 14 States and provinces. After 4 years, seedling families produced by ten trees within a single stand ranged from 18 to 35 inches in mean height, while the overall averages for each of 20 stands fell between 19 and 29 inches. Efficient yellow birch breeding programs will require collecting seed from many parent trees throughout the species' range and outplanting seedlings in field tests designed to be converted into seed orchards. NC(801).

585. Rapid-growing trees with the potential to produce useable products are needed to revegetate acidic strip-mined land. In planting trials on spoil banks in southeastern Ohio, European alder trees have grown well. The tallest 20 percent of the trees in the best seed source (southern Germany) averaged 20.4 feet tall after 7 years. Multiple stems were more common among slower growing trees. Seed has already been collected from some of the better trees for use in future reforestation programs. NC(807).

586. Use of salt as a deicing chemical on U.S. highways has increased 12-fold during the past 20 years. Its use has caused defoliation, stunting, and even mortality to roadside trees. There is considerable evidence of variation in salt tolerance among, and to a lesser extent, within tree species. Low cost procedures will have to be developed and tested to evaluate species tolerance to salt spray and salt-contaminated soils. Selection and breeding programs already available can then be used to develop resistant varieties for urban and roadside plantings. NE(804).

587. The improvement of sugar maple trees for sap production requires a knowledge of genetic variability within the species. Recent studies on the natural hybridization between sugar maple and black maple showed widespread crossing of these species in northern Vermont. In addition, the species can be easily crossed artificially by using black maple as the male parent and sugar maple as the female parent, but not the reverse. Numerous bark, leaf, and flower characteristics can be used to distinguish hybrids from pure species in the field. These results are useful to geneticists breeding maples for improved sap and sugar production, and aiding them in the accurate identification of the selected trees they are working with. NE(808).

588. Eastern white pine is the most valuable conifer in the Northeast, but reforestation programs have been handicapped by a lack of information on genetic variation related to seed source. In 10-year-old test plantings in nine States, best growth was usually made by trees of local or south-of-local origin. Trees from southern Appalachian sources grew especially well in plantations as far north as central Pennsylvania. Tentative white pine seed collection zones now have been established for the northeastern States. NE(809).

589. Special selection methods are required for breeding programs intended to improve the inherent resistance of pines to air pollutants. A fumigation method has been developed for evaluating resistance of large numbers of trees without destroying any of them. Pine needle bundles are exposed to acute pollutant dosages inside clear plastic tubing and damage is evaluated within a few days. This procedure can be used efficiently to evaluate hundreds of seedlings simultaneously under uniform nursery conditions. NE(810).

590. Selecting genetically superior trees at the earliest possible age is important to a hybrid poplar improvement program. After 15 years in Massachusetts test plantings, measurements indicate that it should be possible to make effective selection and genetic gain for timber rotations as short as l, 4, 9, or 15 years. These findings are essential to efficient hybrid poplar production if intensive "mini-rotation forestry" becomes the accepted practice in the Northeast. NE(831).

591. Interactions among competing genotypes can significantly affect performance of selected breeding populations if trees are tested and bred under different competition environments. Different forms of competition interaction are classified and measured in a greenhouse experiment with loblolly pine in North Carolina. Evidence indicates that at least one form of potentially strong interaction exists. Wider testing of many families should be carried out using similar variables and estimation methods. SE(796).

592. Southern Florida has almost no hardwood species with timber production potential. Among several dozen exotic hardwood species tested over the past decade, *Eucalyptus robusta* is one of the few that exhibits wide site adaptability, fast growth, and good timber form, but considerable genetic variation is apparent within the species. Recently, inferior trees have been removed from a test plantation in two stages in order to convert the plantation into a seed orchard. Additional seed orchards are being planned and improved seed will soon be available for southern Florida. SE(805,806).

593. Fusiform rust is a severe disease in plantations of loblolly and slash pines in much of the Southeast. Progenies from three superior trees of loblolly pine from Arkansas and Mississippi had much less rust infection after 10 years in a plantation in central Georgia than did progenies from three superior trees from Georgia. The western progenies also were producing more volume per acre. Forest managers could use resistant exogenous sources of loblolly pine for planting in high-hazard rust areas until breeding programs have produced

rust resistant local strains and thereby avoid much loss in wood production over the next 20 to 30 years. SE(823).

594. Specially adapted genetic strains will be required if hardwood trees are to be grown under intensive culture at rotations as short as four to 15 years with mechanical harvesting and sprout regeneration. Four years of study in northeastern Georgia have shown that significant genetic gains can be made for American sycamore. With the use of appropriate nursery and field planting techniques, 5 to 15 percent increase in dry weight per acre can be achieved in each 8-year generation. SE(803,829).

595. Planting trees of local origin has usually been considered a reasonable and practical policy. After 10 years, trees from 34 of 36 loblolly pine seed sources gathered throughout the range of the species grew faster than the local trees in southern Arkansas. Trees from South Carolina coastal sources grew fastest; fusiform rust resistance was best for trees of Texas, Oklahoma, and western Arkansas origin. The fastest growing South Carolina trees produced 30 percent more wood volume than the local trees and this seed source should be considered for loblolly pine forestation in southern Arkansas. SO(811).

596. The appearance of needles, buds, and bark cannot always be depended on to distinguish hybrid longleaf-loblolly pines from the pure species. However, a biochemical technique called electrophoresis can be used to separate distinctive enzymes found in pine needles and their presence or absence can be used as "chemical fingerprints." Before the tests could be used in pine genetics studies, it was necessary to determine which enzymes are most useful. Nine of 53 enzymes examined were found to be potentially suited for use by geneticists. SO(812).

597. Tree breeders need to know if seed collected from the same trees in different years is genetically consistent. A series of crossing studies made in a stand of native white pine in central Ohio indicates that results are repeatable and thus a single year's test should be sufficient. Furthermore, by careful control of the environment in the greenhouse and nursery, it was possible to select fast-growing families after only 1 to 3 years. These results can be used by tree improvement workers to speed up the progress of genetic selection and breeding programs. SO(814).

598. Sweetgum is a prime candidate for inclusion in genetic improvement action programs, but additional information is needed as to which traits should be emphasized and whether broad or limited planting zones should be established. Studies made at two Mississippi locations showed that genetic gains can be made by selecting trees of above average height and diameter growth rate, but not by selecting for improved branching habit. It also appears that most selections will be useful only for limited planting zones. SO(817).

599. Prospective genetic gains in eastern cottonwood may not materialize if trees found to be genetically superior in one test are not consistently above average when planted at different times or in other locations. Studies in western Kentucky, southeastern Missouri, and western Mississippi have shown that year-to-year variation in growth of cottonwood clones (groups of genetically identical trees) is not critical. Clones did not perform consistently from location to location, especially if there were major differences in site quality. These findings must be considered in the design of trials intended to evaluate the suitability of cottonwood clones for commercial planting. SO(816,820).

600. Cherrybark oak is an important timber species in southern bottomland forests but seedlings usually grow quite slowly for the first few years after planting. There appears to be a good prospect for genetic improvement of early growth rate. In one plantation in western Tennessee, seedlings from local parent trees grew 1.9 times as fast as those from Mississippi and Arkansas, and in another, seedlings produced by specially selected parents outgrew average seedlings by 18 percent. There were also sizeable growth differences among the same collections of seedlings planted in Arkansas, but the variation did not follow a distinct pattern. It is not yet possible to outline the details of a tree improvement program for cherrybark oak but the opportunities for progress are good. SO(818,819).

601. The generally poor early growth of longleaf pine has restricted its use in planting programs in the South. But research results in southern Mississippi offer promise of considerable increase in growth rate through genetic improvement. In a study of seedling families originating from 100 parent trees, those among the tallest 10 percent at age eight produced 43 percent greater than average cubic volume at age 15. Thus, testing of seedling families for early height growth should precede selection of parent trees to be used in longleaf pine seed orchards. SO(824).

602. If it is great enough, genetic variation associated with geographic seed source can be used to establish faster growing forest plantations. In a southern Mississippi study, shortleaf pine from Texas, Louisiana, and southern Georgia produced almost 2.5 times as much wood per acre at age 9 as trees from New Jersey, Missouri, and Pennsylvania. Land managers can use this information to select an appropriate source of seed for areas to be planted to shortleaf pine. SO(115,828,830,840).

2. Tree breeding methodology

603. Many desirable parent trees have to be omitted from seed orchards because they prove to be incompatible when grafted onto rootstock trees. In Douglas-fir at least part of this incompatibility is related to differences in growth stage of the scion and rootstock at the time of grafting. By grafting earlier or later in the growing season, Douglas-fir seed orchard managers may be able to propagate trees where it was previously considered to be difficult or impossible to do so. PNW(842,861).

604. In many species of forest trees there are no biological barriers to self-pollination; trees also frequently grow in family groups that provide a good opportunity for cross-pollination among related individuals. Considering both of these factors, some inbreeding can be expected among seedlings grown from seed collected in natural forests. In several Douglas-fir stands in western Oregon this natural inbreeding is estimated to result in reduced volume growth averaging 4.5 to 6 percent, reaching as high as 20 percent for individual trees. At least part of this growth loss can be avoided by establishing seed orchards that are designed to separate related trees by distances sufficient to minimize their cross-pollination. PNW(859).

605. Inbreeding is an important technique used in genetic improvement of many crops, but inbred forest trees often suffer from seedling mortality, delayed cone production, poor seed yield, and other problems. Researchers at Moscow, Idaho, have found that none of these problems are serious enough to preclude the production of inbred lines of western white pine. Their collections of pedigreed western white pine afford the first-ever opportunity in the United States to test the practicality of producing improved hybrid forest trees by crossing among inbred lines. INT(839).

606. There is an increasing demand in the Midwest and Eastern United States for fast-growing walnut trees that will yield both high-quality timber and superior nuts. A multiple-objective seed orchard system has been proposed that will allow several desirable characteristics to be emphasized. Where this system is used, the customer would be able to specify seedlings selected for traits that are most important to him. NC(838).

607. In tree species that tend to be genetically uniform, the gains from tree breeding will be small and the rate of progress slow unless additional genetic variation can be induced. River birch is one such relatively uniform species and in a study in northern Wisconsin, pollen irradiation was used to stimulate genetic variability. At 8000 roentgens of radiation, the highest level tested, 53 percent of the seedlings produced by pollination with irradiated pollen were visibly different from the normal river birch seedlings. Geneticists and tree breeders working with river birch and similar species should consider pollen irradiation as a possible method of gaining new and desirable heritable variation. NC(841).

608. Research on new tree breeding techniques can proceed more rapidly by utilizing rapid-growing, early flowering species. Studies conducted in northern Wisconsin suggest that jack pine may be just such a "guinea pig" for use in forestry experimentation. In contrast to other species which may require 10 to 30 or more years before producing flowers, 17 to 23 percent of the jack pine seedlings tested flowered when only 17 months old. Such early flowering seedlings can be used in studies of successive generations for selection and breeding towards improved growth and quality. NC(850).

609. Cuttings taken from mature sugar maple trees are very difficult to root. Cuttings more than 6 inches long rooted notably better than shorter ones in a study in northern Vermont. Whenever possible, sugar maple breeders should collect long shoots for propagation work. NE(844).

610. Mature sugar maple trees are quite difficult to reproduce by rooting stem cuttings. Large cuttings collected in late spring root best, but most rooted cuttings do not live through the following winter. In addition, rooting success varies greatly from tree to tree. Although limited, these findings can be used by sugar maple breeders desiring to reproduce selected superior trees. NE(845,858).

611. Loblolly pine is the most important species in the southern pine region because it makes up about one-half the softwood growing stock. A research paper from North Carolina summarizes current knowledge of the genetics of loblolly pine in the areas of 1) sexual reproduction, 2) asexual reproduction, 3) variation and inheritance, 4) interspecific hybrids and, 5) improvement programs. This report will give geneticists and land managers an up-to-date working guide for breeding and orchard management of the South's most valuable species. SE(846).

612. Attempts to graft mature longleaf pine for the rapid establishment of seed orchards frequently fail. Grafting success is much more likely if hybrid slash—longleaf pine seedlings are used as rootstocks instead of longleaf pine seedlings. In one greenhouse trial using the hybrid rootstocks, 360 of 367 attempted grafts were successful. Hybrid seed is available for tree improvement specialists who wish to produce seedlings for use as rootstocks. SE(847).

613. Seed orchard managers have been troubled by the fact that some slash pine orchards are producing heavy cone crops while others of the same age are not. Tallies of cone production in seed source test plantations in Florida suggest that geographic location may account for part of the difference. Early cone production was 10 to 20 times greater in a south Florida plantation than in a similar one located in the northern part of the State. Managers of reforestation programs should consider locating new slash pine seed orchards near the southern end of the species range. SE(848).

614. Vegetative propagation of some commercial hardwood species is difficult and the need to develop methods of preserving clonal lines is important. Sweetgum was propagated successfully from stem cuttings in a growth chamber modified to include an intermittent spray mist. Rooting of specific clones of yellow-poplar was also enhanced in the chamber. This procedure developed in Georgia increases the opportunity to develop clonal hardwood lines for seed orchards and to increase the quality of hardwood stock for plantations in the South. SE(852).

615. Continued breeding within a population of trees grown from selected genetically superior parents can fail to produce expected gains because of inbreeding among related trees. Scientists at Olustee, Florida have devised a new mating scheme for slash pine which will minimize this problem and allow continued genetic gains for growth, disease resistance, and other desirable traits in addition to high gum yield. The scheme should be considered for breeding programs involving other species for which considerable genetic improvement has already been made. SE(860).

616. In some southern pine seed orchards, seed quality has been unsatisfactory because of inadequate pollination. Mass dusting of pollen is suggested as one way to solve these questions. In the future, seed orchard managers need to test mass pollination on a large scale to find out if the practice is economical for their orchards. SE(863).

617. Pollen should be tested to find out if it will germinate and grow satisfactorily before it is used in tree breeding work, but time is often a limiting factor. A new technique has been developed that allows testing of sweetgum pollen in only 4 hours. Tree breeders can use this procedure to determine the precise amount of pollen required to make controlled crosses. SO(837,843,849).

618. Cottonwood cuttings with maximum potential growth capacity are needed for planting on highly productive sites in the lower Mississippi Valley. This need has been recognized for many years and a systematic program of genetic improvement begun in Mississippi in 1960 is now culminating with the release of 14 superior clones (genetically identical collections of cuttings). This group of clones is being extensively planted and forest managers can expect to grow trees that average 20 percent larger in diameter and 11 percent taller than average cottonwoods. SO(851,856).

619. Genotype-environment interactions are recognized as potentially important in breeding, testing, and selection phases of cottonwood improvement. In a Mississippi study, interactions between clones and sites were statistically significant for height, diameter, and number of first-year branches. The results strongly suggest that research emphasis should be placed on testing over a range of sites rather than replicating over time. These results are of particular importance in developing an effective cottonwood improvement program. SO(855).

620. In the near future seed orchards are expected to provide practically all of the requirements for southern pine seed. If the selected parent trees prove to be incompatible with the rootstocks they are grafted on, or if they fail to produce the expected quantity of seed, plans for genetic improvement of southern forests may be seriously delayed. In southern Mississippi, 5 species of pines (loblolly, slash, spruce, pond, and shor-

tleaf) were compared to find which was best suited to use as grafting rootstock in loblolly pine orchards. Among those tested, spruce pine caused dwarfing of the loblolly pines which may be desirable in some situations. Slash pine proved to be the best overall rootstock. These results provide the seed orchard manager with additional information on the best choice of rootstock for his orchard. SO(857).

621. By selective tree breeding, it is possible to produce hybrid forest trees which grow fast and are resistant to insects, diseases, and drought. In order to accomplish these goals, the PL-480 program in Greece supported research to learn whether or not important pine species of the Mediterranean region could be successfully crossed. Crossing was quite difficult, but by carefully selecting certain pine races and by treating pollen with x-rays, certain rare pine hybrids were obtained. This information, especially the identification of compatible races, can be directly applied in accelerating the U. S. pine hybridization program. WO:TMR(835,836).

622. In California a majority of female pine conelets abort before they reach maturity, apparently because of inadequate pollination, nutritional stress, or adverse climatic factors. Several growth regulators were applied to unpollinated knobcone pine conelets; among these, gibberellic acid at concentrations of 4 to 10 percent was most effective in reducing abortion. Similar treatments may be useful for increasing cone and seed production in pine seed orchards. WO:TMR(853,854).

623. The use of irradiated pollen in plant breeding sometimes produces vigorous plants that grow faster than seedlings from the same parent produced with normal pollen. In experiments carried out in Yogoslavia and supported by PL-480 funding, pollen of willow, spruce, and two species of pine was irradiated with gamma rays to study possible acceleration of seedling growth. A large proportion of the seedlings produced with irradiated pollen were dwarfed, but a few were more than 50 percent taller than average after one year in the nursery. The relative growth advantage of these "plus seedlings" seems to be gradually declining, but if they continue to be superior after several years of field testing, irradiation may prove to be a useful method for use in American tree breeding programs. WO:TMR(862).

C. Improving Uses and Protection of Wood

1. Utilization potential and processing of wood

624. The cores of eucalyptus (*Eucalyptus robusta*) logs usually consist of brittle wood which comprises 10.5 percent of the timber volume. This "brittleheart" has been found to have only 26.6 percent of the toughness of normal wood and has a characteristic end grain appearance. Though wood from the "brittleheart" is unsuited for many uses due to the strength deficiency, the characteristic end-grain does allow the segregation of brittleheart from the normal wood. PSW(1115).

625. Wood from old saligna eucalyptus trees, grown in Hawaii, has some undesirable density and shrinkage characteristics that may not occur in wood from young trees. Lumber from 12-year old trees is generally low in grade, but has desirable lower density. Although it cannot compete well with softwood in density and workability, it may be suitable for use in construction, furniture frames, and pallet lumber. PSW(1116).

626. Untreated wood posts decay rapidly in Hawaiian soils. Pressure treatment of round ohio and robusta posts with chromated copper arsenate or pentachlorophenol results in at least a doubling of the expected 5-year service life for untreated posts. PSW(1117).

627. An intensive wood quality evaluation was conducted to determine whether sites in Missouri and Indiana produce walnut of equivalent machining, mechanical, and physical properties. The Indiana-grown wood was found to have higher luminance, less extractives, greater shrinkage, thinner cell walls, and smaller vessels than the Missouri-grown. Machining properties are acceptable regardless of site. Timber buyer preference for walnut grown in specific areas can therefore be partially explained on the basis of differing wood properties. FPL(1111,1129).

628. A major problem confronting forestry is how to more efficiently harvest and utilize timber without creating unaccepatable impacts on the forest environment. There are two immediate and related needs—first, to improve recovery and use of the total wood resource, and second, to reduce adverse esthetic and biological impacts of timber harvesting. The use of forest residues in structural particleboard is one example which may satisfy both needs. FPL(1044,1060,1061,1136).

629. Creosoted pine poles, both in storage and service, lose large quantities of preservative by volatilization. To evaluate supplementary treatments of utility poles in a high rainfall, high decay hazard environment, groundline wood preservative formulations were applied to weathered southern pine pole stubs initially treated with creosote. After 5 years of ground contact, the creosoted controls were severely attacked by decay fungi. The groundline treatments were highly effective in preventing decay and can thus extend considerably the service life of pole systems. FPL(1051).

630. This study reports the energy required to dry wood down to different moisture content levels, under alternative drying schedules. The results of the study indicate that there is no significant difference in the total electrical energy (watt-hours) required to dry wood to a specific moisture content using (1) constant oven termperature, or (2) constant board surface temperature. An increase in either specific gravity or initial percent moisture content increased the watt-hour requirement. INT(1087).

631. A real need exists for a gap-filling adhesive that will bond lumber and plywood into structurally efficient and serviceable building components capable of carrying high and long-term loads. A conventional phenol- resorcinol resin glue was modified with asbestos or walnut shell floor fillers. Glue joints produced were durable and high strength even when glue filled gaps were as much as 0.06 inch. Such a "gap-filling" adhesive provides a new structural bonding resin for on-site construction of engineered structures. SE(1128).

632. The bonding of wood in various applications has recently been reviewed. Topics include properties of wood that affect adhesive bonding, preparation of wood for building, types of adhesives used, factors in selection of adhesives for various applications, factors that affect joint quality, and test methods. SE(1045).

633. Conventional planer shavings are normally a weak particleboard ingredient. Hardwood flakes from cross-grain knife-planing, as a modification to conventional planing, are shown to provide an excellent source of raw material for particleboard and provide smooth planed surfaces. Cross-grain planing should be encouraged so planer shavings may be utilized in higher performance particleboard. NC(1125).

634. Machining methods to improve surface quality of *Populus* spp., which characteristically develop both fuzzy and chipped grain, are needed. The maximum depth of defect was less for cross-grain than for along-the-grain knife planing at much higher feed rates, depths of cut, and rake angles. Fuzzy grain was reduced and chipped grain eliminated by cross-grain

knife planing. Excellent flakes for particleboard by these machining procedures. NC(1121).

635. In searching for methods to knife plane dimension stock from low-grade hardwoods, face milling was tested. Cross-grain knife planing can be applied to short pieces with conventional cabinet planers, but techniques have to be improved and/or developed for material exceeding several feet in length. Initial results show that surface and flake quality can be improved by feeding stock in the down-milling and using an edge radius on the cutter. A downmilling situation utilizing a "face mill" with proper tool geometry, feed speeds, and cutter spin appears to be a promising way to improve dimension stock or lumber surfacing and flake manufacturing. NC(1122).

636. Wood processors require technical information to select the most efficient planing method to conserve energy and raw material. Regression equations were developed to estimate and compare power requirements for abrasive and knife planing of hardwoods. The effect of moisture content and machine variables on power requirements and belt loading are presented. A comparison of stock removal rates for abrasive and knife planing can be estimated. Wood processors can now readily choose the more efficient planing method. NC(1123).

637. Recent studies show that although the high-quality black walnut supply is diminishing, much untapped material is still available. The trees growing on nonforest land, as well as logging residues can supply many of our needs. That low-quality material can be utilized has been demonstrated by woods residue recovery and conversion into products. The manufacturer who practices close utilization can use the additional black walnut sources profitably. NC(1058).

638. In hardwood seasoning, slow drying and defects induced during drying are common problems. Displacement of the water by a series of miscible polar and then nonpolar, highly volatile, low-surface-tension solvents is done before drying. A significant reduction in both drying time and volumetric shrinkage of small specimens after using a methyl alcohol-acetone-pentane series offers promise for minimizing these common problems. NC(1047).

639. Mixed stands of aspen and paper birch are common in the Lake States and tamarack is also available in the same areas. Only aspen is currently used for particleboard; but harvesting operations and small tree utilization in the region could be greatly improved by incorporating a mixture of all three species in particleboard manufacture. Structural particleboard of the wafer type was made using various proportions of aspen, paper birch, and tamarack with 4 percent phenolic resin. Addition of two-thirds tamarack, or one-third birch; or one-third of both tamarack and birch to aspen should produce a commercially acceptable particleboard. NC(1064).

640. The forest floor could be utilized as a filter medium for sewage treatment plant effluent, both increasing forest productivity through fertilization and aiding in final treatment of sewage waters. Changes in wood properties of red pine were monitored for 4 years while red pine trees were irrigated with varying quantities of effluent. Red pine maintained satisfactory wood properties with low rates of irrigation. However, when a large quantity of effluent must be continuously disposed of, species more tolerant of wet sites are desirable. NE(1100).

641. The nation's increasing demand for wood is being supplied from a shrinking forest land base. The need for increased productivity from this land base is obvious. Fertilization offers one possibility in achieving great productivity, but its impact on growth and wood quality is not fully understood. This paper presents an annotated bibliography of the world literature on the influence of fertilization on wood properties. SE(1055).

642. Sand pine, a small, limby, crooked-formed tree that grows on sterile sand sites in Florida would appear to have limited use. A recent review of the literature shows sand pine to have physical and mechanical properties equal or superior to some of the major species of yellow pine and can be used for a wide variety of wood products such as particle board, pulp and paper, veneer, and lumber. This species has adequate wood properties to meet the requirements of many different wood products—the deterrents to its wider use are factors other than its basic wood characteristics. SE(1126).

643. Rapid initial growth of plants is essential in the stabilization and reclamation of severly eroded sites where topsoil is removed and infertility and adverse subsoil properties hinder growth. Seedlings outplanted 2 years, fertilized four consecutive years with N, P, and K, and then permitted to grow 10 years showed significant growth responses in height and diameter to N treatments alone or in combination with P and K. Phosphorous and potassium, at the rates used, had no effect on growth. Percentage of latewood and specific gravity were not altered by fertilization. These findings help in providing knowledge to rapidly and successfully reclaim adverse sites. SE(1127).

644. The variation in stem physical properties and seasonal variation in moisture content of yellow-poplar wood and bark is essential information to purchasers and growers of the species. The moisture content and specific gravity of wood and bark showed extreme variation with height. Yellow-poplar wood moisture content did not vary significantly from season to season. This information is very useful to wood products processing operations. SE(1101).

645. The result of mistletoe infection is a lasting deformation of the tree and a decrease in desirable wood properties. An evaluation of lumber yield and quality from infected and noninfected white fir suggested that present quality control methods are ineffective in detecting quality changes. PNW(1131).

646. Information on the variation in physical properties of wood and bark within the stem of living trees is important to those people working in tree improvement. The moisture content and specific gravity of yellow-poplar wood and bark showed extreme variation with height in the tree. The more drastic changes occurred between the stump and 25 percent of tree height, with major changes and some reverse trends in moisture content occurring at breast height. These results indicate that the physical properties of hardwood trees are quite variable, especially in the lower more easily sampled part of the tree. SE(1110).

647. Green-end veneer mill wood losses were determined for coast Douglas-fir, red and white fir, western hemlock, and Black Hills ponderosa pine. Average yield of dry untrimmed veneer was about 55 percent of original block volume for a sample of over 5500 veneer blocks in 13 veneer producing plants. Improved estimates of wood loss and veneer recovery are now available to mill managers for these species. PNW(1134).

648. An urgent need for better methods of appraising the quality of commercial old-growth coast Douglas-fir is recognized. Yields of lumber and veneer were determined from more than 1000 Douglas-fir trees selected from typical sawtimber stands throughout the coast Douglas-fir region. The information presented is useful in appraising, harvesting, and processing this most important raw material resource. PNW(1082,1083).

649. Forest management practices, such as commercial thinning in the Pacific Northwest, are increasing the volume of available smaller diameter timber. The price mill operators can pay for small diameter stumpage will probably be influenced by conventional and profile-type milling processes, the method of lumber pricing and the method of log volume determination. These factors will be of special interest to land managers and timber processors who are faced with increasing volumes of small diameter timber. PNW(1059).

650. Coast Douglas-fir culled saw logs and culled peeler blocks represent a significant volume of underutilized raw material because of anticipated difficulties in processing and low-quality yields of lumber and veneer. Lumber derived from 116 cull logs was primarily utility and economy grade structural lumber, and veneer derived from 59 cull blocks was largely grade C and D. These results are important information for timber buyers, sellers, and processors, and forest land managers. PNW(1102,1103,1119,1135).

651. The conversion of logs to wood products employing a series of cutting operations can result in appreciable losses of material at the end of the process if improperly and inefficiently done. An optimization technique is developed and illustrated for application to a wide range of sequential cutting operations. PSW(1054,1056,1088).

652. Yearly production of pine foliage may approach that of stem wood formation and thus offers a considerable amount of raw material for fiber and possibly chemical uses, but little is known of the basic properties. Such properties as specific gravity, strength and stiffness, heat of combustion, ash content, longitudinal shrinkage, and extractive content were determined for needles from the four major southern pines. These findings should aid researchers in planning utilization studies and encourage industry attempts to find suitable uses for such a material that would extend our renewable raw material supplies. SO(1070).

653. With fuels in short supply, wood materials assume new importance as an energy source. Heats of combustion of ground, ovendry samples of southern pine wood, bark, roots, needles, cones, wood and bark from tops, resinous stumpwood, decay-resistant knots, resin, charcoal, and dried kraft black liquor were measured using a Parr oxygen bomb calorimeter. This information should be helpful in determining the value of waste material for fuel, as compared with other possible uses. SO(1071).

654. Only about 60 percent of each pulpwood-size pine is currently harvested. To obtain information necessary for whole-tree utilization studies, weights, specific gravity and chemical data were determined for each portion of three 22-year-old slash pines: needles, branches, merchantable stemwood, stembark, top above 4-inch diameter, and main root system with a 6-inch-high stump. Weight distribution data indicates that profitable use of all waste portions would result in a 70 percent increase in merchantable material. These findings should aid researchers in planning utilization studies and encourage industry to explore new uses for the currently unmerchantable portions of pine trees. SO(1072,1076).

655. Timber processors need better conversion systems whereby small, fast-grown trees can be made into structural lumber in a desirable range of lengths, widths, and thicknesses. Laminated lumber produced from 1/4-inch rotary-cut veneer is shown to be 10 percent stiffer and has twice the allowable bending strength than lumber band sawn from closely matched logs. Moreover, yield is 50 percent higher by the laminating process. SO(1077,1078,1079).

656. In 1963 about 30 percent of the dry weight of above and below ground parts of southern pine trees were converted to dry surfaced lumber or paper. By 1980, by employing newly available technology—chipping headings, thin-kerf saws, laminated lumber from rotary-cut veneer, high yield pulping--and by more intensive use of roots, bark, and tops, predictions are for 60 percent of the dry weight utilization. SO(1080).

657. Industrial and academic researchers need a review of completed research in the field of wood machining. This paper reviews notable papers in this field and briefly surveys trends in mechanical processing of wood. The publication, which contains 415 abstracts, together with prior wood machining reviews and texts, provides a comprehensive set of abstracts complete from 1957 through 1971. SO(1081).

658. Wetwood, an abnormal type of heartwood, commonly occurs in trees of the genus *Populus*. Lumber containing wetwood is difficult to economically kiln dry. Microbial studies employing electron microscopy indicate that wetwood is formed in the living tree due to bacterial infection. This information is basic to the control of wetwood formation in the processing of wetwood prone species into products. FPL(1094,1099,1107,1108).

659. Declining average log diameters in the West and projected increase in lumber demand have focused on the geometrical problem of recovering the maximum rectangular lumber from a cylindrical log. A computer program, BOF for Best Opening Face, has been developed which accepts the actual sawmilling conditions such as kerf width, sawing variation, and planing allowance, and determines the actual position of the saw lines which will maximize either volume or value recovery. Careful and thorough analysis indicates increases in dimension lumber yield from a given unit of logs of at least ten percent when computer solutions are compared to sawyer-selected, saw-line positions. Continued application of BOF program will result in an appreciably lower raw material demand per MBF of lumber product. FPL(1067,1068).

660. In the United States and Canada there are over 95 recognized log rules bearing about 185 names which leads to considerable confusion regarding their use and comparability. In one publication are the names, method of scale calculation, and comparisons to the International 1/4-inch rule with change in log diameters. FPL(1062).

661. The potential production of a laminated structural material employing rotary-cut veneer to produce an alternative to structural lumber seems feasible and should improve overall utilization. Alternative equipment to dry veneer, reduce processing costs through the location of a lower cost compatible adhesive, and increased veneer yield on coastal Douglas-fir logs are reported. FPL(1109).

662. The strength, durability, and stability of structural particleboard panels may be controlled by using a suitable selection of manufacturing variables. In this study, optimum resin spread was found to be one pound of resin solids per 1,000 square feet of flake surface. Optimum physical properties were obtained with Douglas-fir flakes 0.02 by two inches in size at a panel density of about 40 p.c.f. Greater directional properties could be obtained by orientation of surface flakes or by use of veneer overlays. This information will assist in the development of optimum structural panels for housing and general construction applications. FPL(1084).

663. The durability of particleboard intended for exterior use is important. The weathering charcteristics of 32 board types are reported after accelerated aging and exposure site tests. The results identify processing steps and ingredients affecting long-term exterior performance of particleboard. FPL(1063,1085).

664. Catalyzed resin systems offer the potential of reducing the processing time for particleboards. The use of a catalyst reduced press time about 1 minute (25 percent) for urea-formaldehyde resin systems, but no reduction was found for phenol-formaldehyde resin systems. This shows a catalyst can be employed to advantage with urea-formaldehyde resin systems in particleboard production. FPL(1086).

665. Like other wood industries, the veneer and plywood industry is concerned with yield from the available logs and control of quality in manufacture. As an aid to minimizing these problems, information on the veneer manufacturing process from log to dry veneer was collected. These papers not only describe research that may lead to improved practice, but by collecting this information in three papers, it is readily accessible to forest managers, log buyers, owners of veneer plants, plant production personnel, and finally to those considering research in this field. FPL(1089).

666. One way to supplement the supply of construction plywood would be to use hardwoods. A combination of dense, strong hardwoods like oak for face plies and low-density hardwoods like aspen and cottonwood for inner plies is promising. If research and development continue to illustrate technical feasibility, and the demand and price of construction plywood remain high, the hardwood timber resource could supply a small but significant percentage of the construction plywood needed. FPL(1091).

667. This compilation of veneer properties from several hundred wood species has been assembled through the efforts of many forest products research establishments around the world. Many nations not yet producers of veneer and plywood, are exporters of large quantities of veneer logs. This compilation is a good beginning for providing available information on various species, throughout the world, suitable for veneer and plywood. FPL(1073).

668. A problem with currently used continuous mechanical veneer dryers is the inability to control the final moisture content of the veneer within the limits desirable for further processing such as gluing. This study describes successful control of the final moisture content of veneer by steaming during press drying. Final moisture contents of 4,5-1/2, 7, and 11 percent, plus or minus one percent, were obtained by control of the steaming temperatures. The ability to control the moisture content of veneer out of a dryer can result in less degrade, less loss by shrinkage, and provide veneer more suitable for gluing. FPL(1090,1113,1114).

669. The effectiveness of preservative systems for increasing the service life of wood is of extreme importance to designers and users of wood structures. Since 1936, service life of variously tested and untreated fenceposts have been evaluated in the Harrison Experimental Forest, MS. Certain treated posts had service lives of over 30 years as compared to less than 5 years for untreated posts. Field exposure information of this type is important to the wood-treating industry as well as the general public. FPL(1066).

670. No single preservative treatment adequately protects wood from marine borers in most southern waters. Several dual treatments and some single treatments at high retentions provided total protection whereas the commonly used marine-grade creosote permitted complete destruction of the test panels. Adoption of recommendations based on results to date could easily extend the service life in marine piling and greatly reduce the annual half-billion-dollar loss of marine piling. FPL(1074,1118,1158).

671. In domestic and Indian hardwoods which are difficult to dry, product losses are high due to surface shrinking and cell collapse. Research under the PL-480 program has shown that presoaking in polyethylene glycol, urea, or urea-sorbitol solutions is quite effective for control of surface checking. In wood treated with a hygroscopic chemical like urea, accelerated drying in kilns is possible with suitable control of relative humidity. Presteaming, steam quenching, and hot water treatment generally improve drying rates. Presteaming causes surface checking and, in some cases, greater shrinkage and collapse. Collapse could be avoided with air drying. Prefreezing reduced shrinkage and collapse in high temperature drying of susceptible species to the levels for low temperature drying. FPL(1112).

672. There are two distinct groups of mastic adhesives; those which are as durable as wood, and those which are not. Heat-resistant adhesives in wood-to-wood joints withstood temperatures over 550 degrees Farenheit and a load of two pounds per square inch. Nonheat-resistant adhesives failed at temperatures generally below 300 degrees F. Not all of the heat-resistant adhesives develop their heat resistance within a period of one month. As properties of mastic adhesives are better known they will find wider use in the construction and building industries. FPL(1065,1105).

673. Wood density and uniformity can provide useful guides for determining the suitability of wood materials for many end products but these wood features are difficult to measure. A new x-ray method was devised in California to assess density distribution in wood, thus making it possible to obtain a more rapid and reliable estimate of quantity and quality of wood in standing trees. This method was applied to the wood density within and across growth rings of three important timber species. Lodgepole pine was found to be most uniform, followed by ponderosa pine and Douglas-fir. PSW(865).

674. Wood grown under the maximum-fiber-yield concept may not be suitable for some uses. Studies in the Lake States with cottonwoods and other poplars have shown that stems of trees grown this way contain a large proportion of fibers composed of gelatinous layers and have surface defects. These deficiencies lower the strength of individual fibers and adversely affect the uniformity of woodpulp; they must be considered when appraising the suitability of trees grown under short rotations as a source of fiber. NC(866,867).

675. Frequently, the quality of fast-grown wood from superior sites is considered satisfactory, whereas the quality of similar wood produced through improved cultural practices, such as thinning or fertilization, is questioned. Much of the confusion results from the lack of uniform criteria to evaluate both the effectiveness of a silvicultural treatment and the quality of wood produced. Three attributes of coniferous tree growth and wood formation—ring width, ring structure, and ring uniformity--provide adequate means for evaluating the quality of fast-grown wood, irrespective of the conditions under which it is grown. NC(868).

676. Softwood plywood production in the South began in 1964 and now accounts for 30 percent of the total U.S. production. A report tabulates veneer volume, 2 by 4 studs from peeler cores, and residual pulpwood for planted slash pine trees. These tables are valuable for predicting the outturn of all primary products of peeler trees for a given diameter and height and will substantially improve a landowner's or purchaser's estimate of standing wood value. SE(864,1180).

2. WOod chemistry and fiber products

677. The effects of wood and pulp properties on dry-formed hardboard need to be determined if industry is to utilize new sources of raw material, such as logging residues, thinnings,

and recycled wood and fiber. For dry-formed hardboard produced with alkaline-curing phenolic resins the effect of pulp pH is most important. All of the hardboard strength properties increase and linear stability decreases with increasing pulp pH. These results indicate that a wide range of raw material may be used for the production of hardboard. FPL(1157,1173).

678. The continuous release of small amounts of formaldehyde from particleboard, fiberboard, or plywood panels is objectionable in housing construction. A simple nondestructive test is proposed, which can be routinely used on any board leaving a production plant. A spot color change dependent upon formaldehyde liberation from the board is the key. This test provides a heretofore unavailable way to detect formaldehyde odor hazard in wood panels. FPL(1147,1200).

679. Paper strength is dependent largely upon interfiber bonding. Bonding strength increases with more intimate interfacing of fibers. When wood fibers are broken down into the ribbonlike fibrils the resulting more flexible ribbons interlace to form stronger sheets. When wood fibers are placed in torsion, they tend to unwind, separating into ribbons having greater surface and conformability for interribbon bonding. If practical industrial equipment can be devised to accomplish torsional unwinding on a larger scale, it is likely that such mechanically-produced, high-yield pulps could be strong enough to replace lower yield chemical pulps in many applications. SO(1154).

680. Oak species have not been used to any great extent in the manufacture of hardboard because of the generally low strength and poor linear stability of the resulted boards. Wet formed, high-density hardboards that meet commercial standards can be made from 100 percent red oak high-yield pulp by using one percent phenolic resin. The dimensional movement is somewhat higher than that for most boards, but this can be minimized by raising the resin content to 2 percent. Dry-formed boards can be upgraded to meet commercial standards by reducing the pH and by increasing the phenolic resin content. Lowering the pulp yield portion is beneficial for board strength, but undesirable for good linear stability. FPL(1169).

681. Pulpmill and papermill residues presently burned or buried constitute a disposal problem. These residues can be used as a carbohydrate substrate on which to grow protein-rich microorganisms for animal feed. Protein-rich fungi will grow on all hardwood pulp and on softwood pulp containing less than two percent lignin. Most pulp residues are digestible by ruminants and have low ash and heavy metals content. Sawdust residues can serve as a roughage in dairy cow rations. The single-cell protein, fibers, and sawdust can be safely used as ruminant animal feed ingredients and supplement expensive hay and feed grains. FPL(1138,1155,1164).

682. Most of the one million tons of waxed corrugated container board produced annually in the United States is now burned or disposed in landfills because of the difficulty involved in removing wax. A recently developed Forest Service system for repulping wax-treated board was shown to produce fiber suitable for corrugating medium. New data show that this recycled material is also suitable for hardboard manufacture when blended with equal amounts of virgin fiber. Wax in the waste can be substituted for the wax normally added to hardboard. This provides another high-value use for the high-quality wax-treated wood fiber formerly discarded as waste. FPL(1170).

683. Pulping trees with the bark included yields 4 percent more fiber from the log and eliminates the need for debarking but also requires relatively more chemical and cleaning to obtain pulps of an equal quality. An economic analysis has shown an economic advantage of $4.68 per bleached ton of paper for the rough wood mill. By increasing fiber yields per tree and permitting the utilization of small, difficult-to-debark trees, rough wood pulping is a viable procedure for extending our wood supplies. FPL(1137).

684. Closely spaced, rapid-growth, young, hybrid poplar yields a large volume of pulpwood per acre. However, the pulping characteristics and pulp properties of some poplar varieties have been unknown. The "Wisconsin 5" poplar produces highly acceptable pulpwood in the 11-24 year age bracket. The very young, short rotation (1-5 years) hybrid has high growth rates that are more than twice the average of managed stands but pulping yields from these whole-tree chips are 40 percent lower. Paper strengths are also lower. Very young trees of the "Wisconsin 5" variety are, overall, much less desirable pulpwood than either slower growing natural aspen or the hybrid trees that are more than 11 years old. FPL(1153,1172).

685. Oxygen bleaching of paper pulp offers environmental advantages over the use of sulfur and chlorine compounds. The oxygen process is coming into use but has the disadvantage of causing excessive degradation of the cellulose fibers. The addition of potassium iodide with magnesium ions improves strength properties of oxygen-bleached papers sufficiently to overcome this disadvantage. FPL(1156,1165).

686. Pulpwood chips deteriorate in outside storage piles at a rate of one percent per month loss in mass. Bacterial action on fresh chips causes a significant portion of the temperature rise in chip piles; the high temperature alone can cause serious degradation of stored pulpwood. Anaerobic storage systems were evaluated for effectiveness for stored pulpwood chips. Douglas-fir chips stored under water, or under a mixture of 95 percent nitrogen, 5 percent carbon dioxide for periods of up to 26 months show no significant losses in pulp yield or paper quality; chemical treatment with sodium-N-methyl dithiocarbamate also prevented deterioration of chips in simulated open-air piles. FPL(1142,1143,1144,1166,1167,1168).

687. Data on specific gravity of major tree species of Alaska are needed to determine strength and working properties of wood and to indicate pulp yields and wood weight. Average tree specific gravity is higher for western hemlock (0.399) than for Sitka spruce (0.380). Specific gravity increases from base to tip of tree in Sitka spruce but varies little over most of the stem length for hemlock. Increment core specific gravity at breast height is significantly related to tree specific gravity for both species. Study results will provide basic information for future work on relating specific gravity to various tree and environmental characteristics in Alaska. PNW(869,870).

3. Wood engineering

688. Woodpeckers often make extensive excavations in utility poles, reducing their service life considerably. Two methods for estimating strength loss in 50-foot, class two southern pine poles proved to be conservative when applied to results of field tests. The results could be used by utility companies for systematic removal of damaged poles if the cost of timely replacement could be balanced against the cost of pole failure and subsequent replacement after failure. SO(1201).

689. Composite load-bearing sandwich panels have high potential for use as alternate building materials, but existing technical information has been largely fragmented and scattered. Technical information pertaining to structural design,

joining methods, durability, acoustical properties, and fire performance was gathered into a state-of-the-art report. This information is essential for proper design of sandwich composites. The use of such panels helps extend our limited material resources to satisfy future housing needs. FPL(1188,1199,1205,1207).

690. Manufacturing plywood in longer, standard lengths could provide efficiencies and economies in manufacture and use as well as decided structural advantages. The concept of a sheathing plywood wherein the grain direction of the face plies is perpendicular to the panel length was recently explored. Panels can be fabricated to continuous length to meet needs for roof and floor spans. An analysis allowing veneers to be proportioned to produce plywood having minimum deflection is given. Information is useful to engineers, designers, builders, and plywood manufacturers. FPL(1193).

691. Trussed rafters are widely used in building construction despite the fact that their longtime service performance has never been evaluated. After 5 years, loaded trussed rafters with seven different connection systems—including nailed plywood gussets, glued plywood gussets, and several metal plate connectors--had deflections about two to three times the initial deflection. Total deflection was still at an acceptable level, however, and strength of the trusses was not appreciably different from that shortly after manufacture. FPL(1208,1209,1212).

692. Fire safety in buildings has made the smoke generation potential of building materials an increasingly important factor in their acceptance. Study results indicate several fire-retardant and nonretardant coatings are effective on plywood for reducing smoke yield under nonflaming exposure, but are relatively ineffective in reducing smoke under flaming exposure. These evaluations and efficiency ratings are valuable to researchers, code groups, and coating manufacturers interested in performance, modification, and improvement of coatings. FPL(1179).

693. Motor Vehicle Safety Standard No. 302 now specifies burning rate requirements for materials used in vehicle occupant compartments. Many of these are wood or wood-based products. Fire performance tests on selected products with the new test method showed that wood and wood-fiber products in general have burn rates well within the allowable limitations. Material suppliers, highway safety officials, vehicle manufacturers, and consumers will find this information useful. FPL(1184).

694. Building officials have been concerned that available types of "solid-core" wood doors may lack equal and acceptable resistance to fire. Research showed that four of five types of "solid-core" wood doors could withstand 30 minutes of fire plus the hose stream exposure specified by ASTM standards. Doors produced under industry standards are now accepted. FPL(1178,1181).

695. Alternative methods of exposure testing, one at FPL and one at the Underwriters' Laboratories, were included in ASTM Standard D 2898-70T. Although equivalency of the two methods had never been established, results of a cooperative study showed that, overall, exposure by either method is suitable to differentiate between leach-resistant and nonleach-resistant wood treatments. This provides the treating industry and laboratories with a choice of two proven exposure methods, and provides the basis for full status recognition of the tentative standard. FPL(1185).

696. The light-frame building is predominant throughout the world; research to produce technological advancements in this construction technique can have significant effect on material conservation. An overview of light-frame construction and an appraisal of research needs was prepared by Dr. Suddarth, engaged by the Forest Products Laboratory for that specific purpose. Wood research needs in building materials, joining systems, building elements, whole building performance, and building regulations are discussed, as well as programs required to meet them. FPL(1206).

697. Structures are often subjected to devastating natural forces whose exact magnitude is unknown to the design engineer. Therefore, he must rely, in part, on design criteria developed from observations of construction details of buildings withstanding or destroyed by such forces. Surveys made of the behavior of structures following hurricanes or earthquakes show that failures result from inability to act as a unit. Wood buildings securely tied together from foundation through roof have been found to withstand terrific punishment. Principles developed from surveys are extremely helpful in providing improved structural design to withstand violent forces. FPL(1192).

698. The service life of a timber bridge can be greatly extended by improvements of one weak link, the timber deck. Experimental evaluations have shown that a vertically glued-laminated panel deck is far superior to a conventional nailed-laminated deck. Design procedures for the glued-laminated deck and the necessary panel deck connectors were developed. Such information has resulted in revised specifications for timber bridge decks and should result in extending the wood resource through more efficient design and longer lived structures. FPL(1195).

699. The present glued-laminated industry in the United States was founded on research which dates back to the 1930's. However, during the 1960's, related engineering technology for large timbers was developed through an extensive research effort. This recent research established the effect of several factors on strength and design of large timbers, especially the effect of tension lamination quality on beam strength. This has resulted in revised specifications for glued-laminated timbers which insure a more reliable engineering material and more efficient use of available timber. FPL(1177).

700. Particleboard may be used to supplement other structural materials if design stresses can be established. A prerequisite to this is the determination of the engineering properties of the material. Basic strength and elastic property data have been developed for a number of commercially manufactured particleboards, and the relationship and correlation between various properties expressed. Need for broader testing to correlate properties and manufacturing variables is indicated. Information is of particular use to code and standards groups, design engineers, and others interested in alternative structural materials. FPL(1196).

701. Relationship between moisture content changes and hardboard properties must be determined if hardboard is to be used in structural applications or supplement other building materials. Effects of equilibrium moisture content on strength and elastic properties of tempered hardboard and property changes that may be anticipated on exposure to varying relative humidity are documented. Results are important to engineers, architects, and others who must be able to approximate effects of moisture change on mechanical and physical properties. FPL(1197).

702. Pallets use over 10 percent of the Nation's annual lumber cut; therefore efficiencies in manufacture and use can greatly aid in conserving timber supply. Service life of wood pallets was greatly extended through use of an impact panel

attached to the forks of a forklift truck to allow handling stresses to be applied to all joints simultaneously. Additional cushioning devices coupled to the panel will increase effectiveness even more. Reduced pallet-trip costs and more efficient use of lumber will benefit pallet users and consumers and conserve timber. FPL(1190,1191,1203).

703. Lumber and wood products are often installed in multifamily dwellings in special ways to provide a reasonable level of sound insulation. Even if this is provided through design, a dwelling can still fail to provide adequate privacy. Tests in apartment developments indicated that results depend not only on actual partition performance but also on the construction surrounding it. Results are important to code groups, builders, and building inspectors because they demonstrate techniques of reducing sound pollution through application of basic concepts. FPL(1182,1186).

704. Improving the overall effectiveness of wood construction to efficiently use our resource is the goal of a broad program of research. Part of this research includes the control of noise in wood-framed-buildings. The resistance to airborne and impact sound transmission has been evaluated for eleven floor-ceiling assemblies. Nailed gypsum board ceilings provide less resistance to sound transmission than suspended ceilings or ceilings applied on resilient channels. A pad and carpet on floors provides much greater resistance to impact sound transmission than does vinyl tile. PNW(1176,1183).

705. Standard pallet fabricating procedures with dense woods often result in nail driving and bending problems, plus board splitting. For better wood utilization and greater efficiency, fabricators need information on alternative manufacturing procedures. Evaluation of low-density woods, optional mechanical fasteners, insertion methods, and adhesive systems indicated improvement or a potential for improvement in both fabricating procedures and pallet performance. The research should benefit pallet producers and consumers alike through better pallet fabrication and performance. FPL(1189).

4. Biological degradation

706. Wood chips piled in outside storage are subject to biodeterioration which may result in average losses in wood substance of about one percent per month. To offset these losses a search was made for chemicals which might prove of value in the control of fungi known to be of importance in the degradation of stored wood chips. Of the 30 chemicals eventually screened against these fungi, 23 proved effective at concentrations ranging from a low of 0.05 percent for 2-heptadecyl-1,5,5,6-tetrahydro-4,4,6-trimethylpyrimidine to a high of 6.0 percent for thiourea. Hence, a number of these chemicals should prove of value in the protection of stored wood chips against biological degradation. FPL(464).

707. The lack of success in using microbes for the conversion of wood, wastepaper, pulpmill wastes, or even feedlot manufacture into useful products can be ascribed to the inability of many organisms to attack the lignin which is associated with the cellulose fibers. Detailed studies are being made of the biochemistry of those organisms which can attack lignin to determine how lignin digestion can ultimately be achieved. The mechanism by which a decay fungus, *Polyporus dichrious*, breaks down one of the chemical building blocks of lignin and the mechanisms by which one bacterium, a *Nocardia*, can break some of the chemical bonds found in the lignin complex have been described. FPL(462,466,467).

708. The question of whether cellulose and hemicellulose in wood are necessarily degraded by lignin-removing fungi was investigated. Results indicated that they are not. Thus, fungal delignification of wood is possible without damage to polysaccharides. This indicated that biological preparation of cellulose fiber from wood may be possible. This could lead to new or improved methods of pulping wood. FPL(465).

709. The relative rates of removal of cellulose, lignin, and the hemicelluloses from conifer woods by decay fungi are poorly known. A recent study provides information on several wood species attacked by white-rot and brown-rot fungi. The glucomannan component is preferentially depleted. Results fill a gap in the understanding of wood decay and hopefully will be useful both in decay control and in the beneficial use of decay fungi. FPL(469).

710. Degradation of lignin is a key factor in the ability of microorganisms to decay wood. Although previously suspected, there has never been firm evidence that bacteria can degrade lignin. In recent experiments at the Forest Products Laboratory, a bacterium of the *Pseudomonas* "acidovorans group" was able to break the single most important bond in lignin. The key enzyme is a mono-oxygenase. This is the first known splitting of this most common linkage in lignin by a bacterium. FPL(463).

711. Cleavage of ether bonds seems to be a key to decomposition of lignin. The capabilities of a white-rot fungus to cleave various ethers related to those occurring in lignin were elucidated. Several unexpected oxygenations were observed in addition to ether cleavages (which also were oxygenative). Results provide information on the kinds of enzymes involved in lignin biodegradation, and thereby the kinds of enzymes important in wood bioconversion. FPL(468,1140,1145,1146,1159).

5. Prevention and control of wood-destroying organisms

712. Because damage by anobiids (a group of wood destroying beetles) occurs slowly and usually is not discovered until buildings are more than 10 years old, homeowners and pest control operators often ignore proper control practices. Four infestations are described for which damage was ignored until it was widespread. In each case early detection and control of damage would have avoided more difficult and expensive control treatments. Annual damage inspections and insecticidal spray treatments of exposed wood when infestations are limited to crawl spaces are recommended to avoid later expensive fumigations. SO(341).

713. Many commercial pest control operators fail to properly identify wood destroying beetles and thus often apply improper or unnecessary controls. A guide for identification of the most common and most damaging wood destroying beetles is based on the typical habits of beetles considering: type of wood, age of wood, and type of products attacked. The acronyms TOW-A-TOP and ALBOW are offered for memorizing the guide and the beetles identified. With proper identification, pest control operators can provide more effective, economical control. SO(342,343).

714. Wood decayed by the brown rot fungus *Lenzites trabea* is attractive to the eastern subterranean termite, but neither the nature of this attractancy nor the advantage to the termite of feeding on this rotted wood is known. The protein amino acid content of decayed wood differed from that of sound wood. Termites feeding on decayed rather than sound wood showed no difference in their protein amino acid composition but they did have a different free amino acid composition. Information on the chemical composition of rotted wood helps in understanding termite nutrition and in designing and evaluating selective techniques of termite control. SO(339).

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715. The Formosan subterranean termite *Coptotermes formosanus* and other subterranean termites can presently be controlled only by substantial applications of nonselective, persistent insecticides. An examination of the Formosan termite, with and without its gut-inhibiting protozoa, demonstrated that the protozoa play an undetected and, presumably, a nonsignificant role in termite protein synthesis. Controlling the Formosan subterranean termite by a selective chemical aimed at disrupting the protozoan's protein synthesis capability does not seem promising. SO(340).

716. In most parts of the world's temperate and tropical zones, underground electrical cable sheathing is subject to subterranean termite attack causing electrical failures and costly repairs. In both the Panama Canal Zone and the southern United States, flexible polyvinyl chloride (PVC) plastics were readily perforated by subterranean termites. By increasing the hardness and incorporating insecticides into the PVC, no termite perforation occurred. Four non-PVC polymers were also resistant to termite attack. Rigid PVC with insecticides added and the non-PVC polymers can be relied on as cable coverings to give many years of service, free from subterranean termite attack. SO(338).

717. Organisms growing in piles of wood chips destroy wood fiber in chips and contribute to a buildup of heat that can also affect fiber quality in the chips. Propionic acid, a potentially nonpolluting biocide used successfully to protect stored grains from microbiological attack and from destructive self-heating, was found to effectively prevent fungal degradation of wood chips in laboratory tests. Field development of a propionic acid treatment for chips may provide a means of preventing fiber losses in chips stored in outside piles. FPL(474).

718. Anaerobic storage has been considered as a means of preventing biodeterioration in wood chips, but the effect that this type of storage had upon quality and quantity of kraft pulp made from chips was unknown. It was found that Douglas-fir wood chips stored under water or in an atmosphere of 95 percent nitrogen plus 5 percent carbon dioxide for periods of up to 26 months were not significantly reduced in specific gravity. In addition, the yields of kraft pulps from these chips and the properties of the pulp handsheets remained essentially constant throughout the storage period. This research has demonstrated to the pulpwood industry that wood chips may be stored anaerobically for fairly long periods of time without fear of losses in quantity or quality of end product. FPL(475).

719. The mechanisms by which fungi break down cellulose in wood are not understood. The addition of some sugars to nutrient media suppressed the production of celluloses by some fungi. This suggests that control of some types of wood decay may be possible by treating wood with nonmetabolizable sugars. FPL(476).

720. The chemical basis for many diagnostic tests used during the identification of wood-decay fungi is not known. A color reaction with potassium hydroxide (KOH) that is used in the identification of slash-decomposing fungi was shown to be due to a difference in pH of the fungus tissue and not due to a chemical reaction with KOH. Explanation of the importance of pH in taxonomic tests provides a useful tool that will aid in identification and recommendation of specific controls for decay fungi in wood products. FPL(471).

721. Wood permeability seems to vary erratically with storage conditions. To clarify the situation, sapwood permeability was monitored at monthly intervals in small piles of southern pine logs stored under a continuous water spray in Mississippi. A small change during the first month of storage was followed by an abrupt increase during the next 3 months. The sharp rise in abosrbency after the first month was associated with destruction of the cell walls in ray parenchyma tissue. This suggests that wood-treating industries can store fresh logs under water sprays for a month with little change, but after that, changes in permeability occur rapidly and are irreversible. Such changes can influence manufacturing costs or product characteristics. SO(473).

722. Recent research describes the extent of chemical and biological change that occurs in southern pine logs stored under water sprays. Research studies on logs stored under sprays during the summer in southern Mississippi indicate that most biological changes occur within the first 4 months of storage. These changes result in no significant reduction in major strength properties; in addition, the quality of the terpene component is retained during storage. This definition of the biologically related changes in logs stored under water sprays confirms that logs are adequately protected by water sprays during storage. SO(472).

723. Many homeowners, particularly in the South, may have houses damaged by decay fungi or termites. A popular publication illustrates these destructive insects and provides examples of wood decay and termite damage in the house. Instructions are given for homeowners and prospective house buyers to follow in checking the biological health of a house. The American homeowner, for the first time, has a practical guide which he can use in inspecting and repairing damage and in making improvements that will prevent future damage to his home. SO(470).

D. Marketing Under-used Species and Residues

724. Prospects appear to be favorable for the production of particleboard in the Black Hills region of South Dakota. An analysis of raw materials, shipping costs, and available markets for particleboard which might be produced in the Black Hills indicates a promising opportunity. The information has been used to advise prospective particleboard producers, area development advisory groups, and others who are interested in expanding rural economic opportunities. RM(950,951,953).

725. Based on corporate expectations in 1971, West Coast pulp and fiberboard industries will expand wood use by 19 percent to 17.7 million "ovendry" tons per year by 1980. Consumption of roundwood logs is expected to remain at 3 million tons per year during the 1970's with additional wood fiber requirements to be met from unused sawmill and plywood plant wood byproducts. At the time of this study, there were no specific plans by the processing firms to utilize substantially larger quantities of logging residues except as these materials were converted to utility grade material and removed at the time of primary harvest. Information on industry's expectations for additional wood fiber use are essential for the formulation of strategies for increasing the utilization of residues from timber harvesting. PNW(948,949,952).

E. Supply, Demand, and Price Analysis

726. "The Outlook for Timber in the United States," the latest in a series of periodic appraisals of United States timber supplies and demands, was published in October 1973. Timber inventories on the commercial timberlands of the United States contained 715 billion cubic feet of wood in 1970. This was somewhat greater than the inventory estimated in 1963. This analysis revealed further that American forests, in

response to programs of forest fire control, tree planting, and other forestry measures registered a gain of 14 percent in net growth between 1962 and 1970. The study also shows that additional investments in timber growing are needed to enable the Nation's forests to meet the expanding demands for wood products without increases in the real prices of these products. This situation may be accentuated by further reductions in the area of commercial forest land and by restrictions on timber harvesting in order to protect and enhance other forest values. WO(959,974).

727. An analysis of the demand and price situation for forest products provides up-to-date information on timber product markets as of 1972. Information is presented on price and consumption trends for lumber, plywood, pulp and paper, and miscellaneous products, including naval stores. WO(954,960,961).

728. A quarterly marketing report on the Northwest forest industries presents current timber industry information on production, prices, employment, trade, volume and average prices of stumpage sold by public agencies, and other related items. PNW(962,963,964,965).

729. Mobile home manufacturing is a significant market for wood products. A nationwide study of wood products consumed by the mobile home industry in 1971 disclosed that almost all manufacturers use wood framing systems exclusively, and that lumber use per unit averages 1,680 bd. ft. Mobile home manufacture also involves substantial use of particleboard, plywood, and hardboard. Since production of mobile homes now totals over 500,000 units annually, information on wood materials use is of great importance to firms supplying products to the mobile home industry, and for analyses of overall trends in the consumption of wood products nationally. SE(957,958,969).

730. Futures trading in lumber and plywood offers an attractive method for southern pine manufacturers to protect themselves against price fluctuations and gain added marketing flexibility. Analyses of hedging practices and strategies are presented. SO(966,967,968,992).

F. Marketing--General

731. Farm building construction is shifting from the farmer to commercial contractors and building manufacturers. Studies in the Midwest indicate that contractors and building manufacturers are becoming the trend setters in the farm building market and have a growing influence on materials used in farm structures. These findings likely are indicative of shifting farm building construction patterns nationally. Sellers of wood products to the agricultural building market should target their marketing strategies accordingly. NC(1008).

732. A method was developed in the northern Lake States to measure diameters of pulpwood accurately and cheaply from photographic slides. This technique will be useful as a research and management tool for determining weight-volume relationships of pulpwood under conditions where work delay constraints or weather conditions prohibit actual outdoor measurement. NC(993).

733. A bibliography of Christmas tree marketing provides up-to-date information on production and marketing. This information assists Christmas tree producers, wholesalers, and retailers in making realistic decisions on production and marketing strategies. NE(991,1000,1003).

734. A linear programing model was developed to determine the least-cost grade mix of lumber inputs for dimension stock orders. Since improving hardwood dimension stock yield is a continuing problem facing the furniture industry, this research provides a basic management tool to assist manufacturers in improving yields and minimizing wastes in lumber usage. NE(975,989,990).

735. The volume of Federal timber allocated to timber sales and sold with intent to export for the period 1969-72 was significantly below the 350 million board foot maximum annual level provided by "The Morse Amendment." (Part IV of the Foreign Assistance Act of 1968—Morse Amendment--limited log exports from Federal lands west of the 100th meridan to not more than 350 million board feet annually.) This analysis of log exports from the West Coast, for the period of 1969-72, provides insights into how the Morse Amendment has been applied to Forest Service and Bureau of Land Management lands, and how it has affected the export of Federal timber. PNW(980,998).

736. A system for the simultaneous weight-scaling of both saw logs and pulpwood in tree-length truckloads was developed by Forest Service researchers in the South. With the advent of tree-length logging and hauling, mills found that they had considerable difficulty in obtaining accurate and quick product measurements when both saw logs and pulpwood products were involved. As a result of this research, any particular mill now can construct weight-scaling tables through use of a simple sampling procedure and a specially developed computer program. This product measurement system, now gaining wide acceptance in the South, provides advantages to both timber sellers and buyers, since it offers an equitable and easily understood measure of multiproduct shipments. SE(977,986,988,1001,1012).

737. The performance of 1,000 wooden pallets of 22 different species and structural designs was evaluated on the basis of laboratory and field tests. Results of performance comparisons provide the basic information to establish pallet construction standards and specifications between "exchange" pallets in a regional or national program of materials handling. Based on these and earlier joint studies between the Northeastern Forest Experiment Station and the National Wooden Pallet and Container Association, the U.S. Postal Service initiated a program of palletized handling of third-class mail in the fall of 1973. In addition, a large private retail firm is conducting a pilot test of the pallet pool concept of materials handling, and anticipates expansion of the program to over 3,000 of its suppliers. In each of these instances, all pallets will be manufactured according to standards developed as a result of this research. These developments should lead not only to savings in materials handling, but also to the more efficient use of wood materials in pallet construction. NE(1005,1006,1009,1010,1011).

FOREST ENVIRONMENT RESEARCH

WATERSHED MANAGEMENT RESEARCH

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environmental effects of pesticides **6** (*344*)
environmental impact **113, 393** (*53, 222*)
environmental impact of camping **89** (*211*)
environmental interpretation **109, 110, 111, 112** (*195, 200, 219, 223*)
environmental law (*916, 921*)
environmental quality **113, 115** (*205, 222*)
enzymatic degradation (*1146, 1159*)
enzymes **596** (*812, 849*)
epicormic branching (*641*)
epicormic shoots **170** (*226*)
epidemics (*561*)
equipment **146** (*497*)
equipment design **364** (*1042*)
erosion **2, 115, 402, 406** (*1, 3, 4, 7, 92, 103, 106, 205*)
erosion control (*2, 5*)
erosion hazard (*8*)
ERTS-1 satellite **450, 451** (*335, 337, 904*)
esthetics **90, 92** (*196, 221*)
European alder **585** (*807*)
European mistletoe **252** (*406*)
European pine shoot moth **175, 201, 202** (*231, 252, 255, 256*)
evapotranspiration **389, 391** (*47, 63*)
even-aged stands (*778*)
exchangeable cations **19** (*15*)
exotic fuel **386** (*1036*)
exotic fuel gas generator **386** (*1036*)
exotic hardwoods **592** (*806*)

experimental forests **415** (*577*)
experimental watersheds **391** (*63*)
exports **728** (*962, 963, 964, 965*)
exposure **663, 669, 670** (*1063, 1066, 1074*)
exposure tests **695** (*1185*)
extractive content **652, 653** (*1070, 1071*)
extractives yield (*805*)

F

face milling **635** (*1122*)
fall cankerworm **235** (*261*)
fall planting (*96*)
farm structures **731** (*1008*)
fasteners **737** (*1005*)
fastenings **697** (*1192*)
Federal research natural areas **76** (*35, 188, 549, 550, 551, 552*)
Federal timber sales **735** (*980*)
feeder roots (*405*)
feeding deterrents **200** (*299*)
feeding stimulants (*257*)
fence posts **626, 669** (*959, 1066, 1117*)
fertility (*94*)
fertilization **408, 466, 512, 519, 520, 521, 522, 525, 538, 539, 643** (*69, 83, 94, 105, 111, 458, 649, 704, 705, 706, 708, 713, 722, 740, 746, 747, 748, 752, 756, 758, 761, 1127*)
fertilization economics **521** (*758*)
fertilization impacts **322** (*437*)
fertilizer burns **476** (*459*)
fertilizer recovery **537** (*738*)
fertilizer response **641** (*654, 1055*)
fertilizers **328, 387, 388** (*32, 68, 435, 546*)
fescue (*26*)
fiber strength (*1172*)
fiber yield **674** (*866*)
fiberboard (*1182*)
fiberwood **725** (*948*)
fillers **631** (*1128*)
financial evaluation **351, 359** (*911, 918, 927, 933, 937*)
fir **185** (*233*)
fir engraver **229, 230** (*263, 264*)
fire **448, 473** (*3, 4, 19, 527, 653, 695*)
fire behavior **138, 140, 141** (*499, 501, 502*)
fire control **139, 140, 157, 157** (*501, 511, 523, 523*)
fire damage **124** (*491*)
fire ecology **27, 50, 75, 77, 78, 81, 157** (*116, 134, 184, 189, 193, 194, 523*)
fire effects **150, 408** (*111, 507*)
fire hazard **137** (*559*)
fire history **135, 164** (*481, 524*)
fire intensity **124, 139, 160** (*491, 511, 519*)
fire laws **122** (*479*)
fire management **27, 81, 140, 147, 151, 152, 153, 154, 157** (*116, 194, 495, 501, 506, 509, 510, 512, 523*)
fire performance (*1178*)
fire prevention **126, 127, 128, 129, 130, 135, 136** (*478, 481, 483, 484, 485, 486, 489*)
fire protection **270** (*375*)
fire research planning **155** (*498*)
fire resistance **672, 694** (*1065, 1105, 1181*)
fire retardance **144, 145** (*494, 496, 504, 505*)
fire retardants **695** (*959, 1185*)
fire risk **455** (*541*)
fire safety **692, 693** (*1179, 1184*)
fire spread **139, 140, 141, 142** (*501, 502, 503, 511*)
fire surveillance **143** (*508*)
fire use **140** (*501*)
firetree (*701*)
firing techniques **123** (*490*)
fish habitat **55, 343, 393** (*43, 44, 53, 156, 876*)
fish management **56** (*155*)
fishermen **100** (*212*)
fishing **91, 100** (*206, 212*)
flake size **662, 663** (*1063, 1084*)
flaming conditions (*1180*)
flight behavior **223** (*285*)
flood potential **389** (*47*)
flood reduction (*37*)
flood tolerance **442, 443, 474** (*603, 616, 657*)
floods (*48, 100*)
flooring (*999, 1176, 1212*)
flower development **514** (*754*)
flowering **332, 526, 535, 539** (*565, 711, 715, 752*)
flowering dogwood (*630*)
flowering shrubs **38** (*140*)
fog drip (*62*)
fog wind tunnel (*62*)
foliage (*78*)
foliar analysis **532** (*760*)
food reserves **484** (*674*)
forage **24, 34, 75** (*120, 129, 189*)
forage digestability **39** (*148*)
forage production methods **22** (*119*)
forage quality **39, 40** (*148, 149*)
forbs (*88*)
forecasting **458** (*534*)
forest acreage **340, 357** (*880, 883, 885, 930*)
forest amenities **67, 68, 69** (*174, 177, 180*)
forest appraisal (*879*)
forest canopy (*57*)
forest cover **396** (*71*)
forest ecosystems **71** (*170, 549, 568*)
forest engineering **364, 365, 368, 369, 370, 371, 373, 374, 375, 376, 377, 379, 380, 381, 382** (*1018, 1019, 1022, 1023, 1025, 1026, 1027, 1028, 1029, 1030, 1031, 1035, 1037, 1040, 1041, 1042, 1043*)
forest fertilization **407, 521, 528, 537, 540** (*107, 705, 738, 750, 753, 758*)
forest fire danger rating **167, 455, 464, 465** (*522, 537, 538, 541*)
forest fire suppression **148, 149** (*500, 513*)
forest fires **81, 448, 449, 458** (*194, 527, 528, 534*)
forest floor **472** (*651*)
forest improvement **501** (*692*)
forest industries **340, 343, 344, 362** (*876, 882, 883, 884, 885, 887, 888, 936, 939, 940, 941, 943, 944, 1014*)
forest land **18, 19** (*15, 16*)
forest land planning (*568*)
forest management **36, 42, 56, 131, 372, 373, 376, 378, 406, 410, 418, 429, 531, 561, 565, 566** (*106, 117, 138, 155, 493, 570, 572, 587, 589, 669, 695, 729, 759, 779, 784, 785, 908, 921, 1018, 1019, 1024, 1027, 1030, 1039*)
forest modeling **350** (*566*)
forest openings (*631, 641*)
forest ownership **339** (*872*)
forest policy **108** (*203*)
forest production (*931*)
forest products **727** (*944, 946, 960, 1103*)
forest products industry **132, 347, 360** (*487, 889, 890, 898, 947, 984, 1007, 1017*)
forest products research **671, 672, 679, 680, 681, 682, 684, 685, 686** (*1065, 1105, 1112, 1138, 1142, 1143, 1144, 1153, 1154, 1155, 1156, 1164, 1166, 1167, 1169, 1170*)
forest recreation **68** (*174*)
forest rehabilitation (*114*)
forest residues **628** (*1044, 1060, 1061, 1136*)
forest resources **341, 343, 696** (*871, 876, 912, 1206*)
Forest Service research organization **696** (*1206*)
forest soils **468, 537** (*647, 738*)
forest surveys **341** (*871, 878, 879, 880*)
forest tent caterpillar **310** (*304, 305*)
forest types **437** (*52, 645*)
forest vegetation (*64*)
forest vegetation control (*546*)
forest yield **545** (*772*)
forestry (*916, 935, 997*)
forestry business economics **649** (*956, 962, 1059*)
forestry workers **4** (*14*)
forests (*37, 94, 100*)
forklift truck **702** (*1203*)
formaldehyde odor **678** (*1147*)
Formosan termite **715** (*340*)
Fraser fir **184, 185** (*233, 235*)
frequency distribution (*987*)
frost **431** (*606*)
frost crack **191** (*361*)
frost damage **574** (*799*)
frost depth **396, 403** (*71, 102*)
fuel break construction **137** (*559*)
fuels **121, 125, 133, 139, 142, 158, 159, 168** (*477, 488, 492, 503, 511, 515, 520, 526*)
fumigation chamber (*350*)
fungal antagonism **257** (*431*)
fungi (*85, 452*)
fungi-host relationships (*611*)
fungicides **314, 315, 328** (*435, 446, 449, 450*)
fungus zone lines **246** (*409*)
furniture (*975*)
furniture assembly **632** (*1045*)
furniture dimension (*989*)
furniture production **734** (*989, 990*)
furniture selection (*975*)

fusiform rust **269, 287, 325, 326, 327, 331, 593, 595** (*378, 379, 380, 381, 407, 444, 445, 447, 448, 452, 564, 811, 823*)
fusiform rust impact (*368*)
fusiform rust infection (*367, 444*)
fusiform rust resistance **326, 327** (*445, 447, 843, 849*)
futures trading **730** (*966, 967, 968*)
futurism **101** (*220*)
G
game bird management (*218*)
game habitat (*29*)
game management **86, 106** (*192, 201, 217*)
gamma distribution **457** (*542, 543*)
gamma radiation **60** (*157*)
gamma-irradiated pollen (*676*)
gardening **93** (*204*)
gene resources (*854*)
genetic breeding (*854*)
genetic correlations (*805*)
genetic gain **601** (*824*)
genetic improvement **520** (*704, 722, 858*)
genetic markers (*849*)
genetic resistance **589** (*810*)
genetic variability **390, 598** (*67, 805, 817*)
genetic variation **574, 576, 577, 584, 588, 592, 594, 595, 597, 598, 601, 602, 604, 618** (*799, 801, 802, 803, 806, 809, 811, 814, 817, 824, 826, 828, 829, 830, 851, 859*)
genetics **583, 611** (*800, 846, 861*)
genotype-environment interaction **509, 575, 598, 599, 619** (*720, 816, 817, 825, 855*)
genotype-fertilizer interactions **540** (*753*)
geography **343** (*876*)
geology **74, 343** (*40, 43, 545, 876*)
germ plasm (*854*)
germination medium **617** (*837*)
gibberellins **543** (*733*)
Girl Scouts **104** (*213*)
glaciated valleys (*9*)
glaze damage (*644*)
glaze storms (*644*)
glued-laminated beams **699** (*1177*)
glued-laminated construction **698** (*1195*)
glues **672** (*1065, 1105*)
gluing **672** (*1065, 1105*)
grading (*1094*)
grading system (*1119*)
grafting **603, 612, 620** (*842, 847, 857*)
grand fir **194, 483** (*246, 358, 678*)
grasses (*88*)
Great Plains forestry **172, 207, 209** (*238, 276, 277*)
green ash **172, 207, 492** (*238, 277, 659*)
greenhouse culture **489** (*682*)
greenhouses (plastic) **487** (*672*)
grey-headed juncos **435** (*634*)
gross data method **365** (*982, 1023*)
groundwater **17** (*17*)
group selection (*631*)
growing season **524, 595** (*726, 811*)
growth **501, 510, 551, 552, 675** (*692, 724, 771, 775, 868, 877*)
growth chamber **614** (*852*)
growth measurements (*44*)
growth predictions **548, 562** (*769, 777*)
growth rate **481, 493, 511** (*668, 689, 728, 819*)
growth regulators **543, 569, 573, 622** (*733, 790, 795, 853*)
growth response **547** (*767*)
growth stresses **624, 625** (*1115, 1116*)
guidelines **123, 138** (*490, 499*)
gully control (*7*)
gum farming **572** (*793*)
gypsy moth **177, 186, 218, 219, 220, 294, 355** (*228, 229, 240, 266, 278, 282, 320, 333, 924, 925*)
gypsy moth predators **218** (*266*)
H
habitat improvement **25** (*126*)
habitat types **433, 434** (*608, 635*)
hackberry (*638*)
halophytes (*620*)
hand planting **530** (*751*)
handsheets (*1172*)
hardboard **677, 680, 701, 725, 729** (*948, 957, 958, 969, 1157, 1169, 1197*)
hardwood bark-sawdust composts (*951*)
hardwood control **505, 527** (*114, 694, 718*)
hardwood dimension **635, 734** (*989, 990, 1122*)
hardwood forest (*36*)
hardwood genetics and breeding (*843*)
hardwood management **359** (*681, 933*)
hardwood pests **239, 241** (*289, 293, 294*)
hardwood residues **655** (*1077, 1078, 1079*)
hardwood sawlogs (*983*)
hardwoods **18, 636, 666, 671** (*13, 16, 38, 590, 596, 632, 641, 699, 747, 756, 778, 1001, 1002, 1091, 1112, 1123*)
harrowing **490** (*667*)
harvesting **345, 362, 726** (*597, 896, 897, 927, 940, 974*)
harvesting equipment efficiency **385** (*1020*)
harvesting methods **417** (*569, 592*)
harvesting systems **368, 371** (*1035, 1043*)
heart-leaved paper birch **561** (*779*)
heartrots **194, 266, 270, 271, 282** (*358, 375, 376, 377, 412, 421*)
heartwood **658** (*1108*)
heartwood formation **278** (*425*)
heat flux **158** (*526*)
heat flux sensor **158** (*526*)
heat of combustion **652, 653** (*1070, 1071, 1180*)
heat sum **535** (*715*)
heat treatments **318** (*441*)
hedging **730** (*966, 967, 968*)
height growth **554, 601** (*762, 815, 824*)
height increment **466** (*649, 654*)
height measurements **559** (*781*)
hemlock sawfly (*875*)
herbaceous legumes **392** (*86*)
herbage yield (*31*)
herbicide applications **422** (*598*)
herbicide drift **505** (*694*)
herbicide spraying **505** (*694*)
herbicides **3, 31, 35, 313, 391, 409, 500, 508, 511** (*12, 38, 63, 110, 130, 132, 443, 461, 662, 695, 699, 700, 701, 728*)
heredity (*737*)
heritability **598** (*805, 817*)
heterorrhizic (*621*)
hickory borer **240** (*290*)
high altitude planting **485** (*675*)
high elevation (*26*)
high temperature (*1076*)
highways (*39, 81*)
Holdridge System **446** (*609*)
honeycomb cores (*1188*)
host range **252, 288** (*406, 408*)
host selection **232** (*283*)
house damage control **337, 723** (*457, 470*)
housing **672, 689** (*1065, 1105, 1207*)
housing trends **696** (*1206*)
huckleberries **116** (*553*)
humidity **165, 454, 458, 458, 459** (*514, 530, 534, 534, 539*)
hunter surveys **53** (*154*)
hunting **86, 106** (*192, 201, 217, 218*)
hunting dogs (*218*)
hurricane (*64*)
hybrid pines **621** (*835*)
hybridization **447** (*643, 833*)
hybrids **587, 596, 684** (*808, 812, 1153*)
hydrologic cycle (*108*)
hydrologic model **398** (*55*)
hydrology (*34, 54, 77*)
hydrophytes (*620*)
hypocotyl cuttings (*741*)
hypoxylen canker **265** (*418*)
I
ignition **128, 141, 142, 146, 158, 462** (*486, 497, 502, 503, 526, 529*)
ignition pattern **166** (*521*)
impact assessment **174** (*237*)
impact panel **702** (*1203*)
impoundments (*22*)
improved seed **592** (*806*)
improvement cuts (*590*)
inbreeding **604, 605** (*839, 859*)
inbreeding effects **615** (*860*)
incense cedar **7, 354** (*353, 567, 628*)
increment forecasting **564** (*787*)
indicator plants **349** (*902, 903*)
industrial wood production **347** (*890*)
industry directories (*1014*)
infiltration **1, 18, 391** (*10, 16, 63, 93*)
information system (*992*)
infrared line scanners **143** (*508*)
inherent variation **600** (*818*)
inhibitors **436** (*642*)
inoculations **267, 325** (*379, 397, 399, 400, 448*)
inoculations eastern gall rust **287** (*378*)
input-output model **360** (*947, 1017*)
insect attack behavior **223** (*285*)
insect biology **173, 207** (*227, 242, 246, 252, 277*)
insect control **332, 521** (*309, 565, 758, 843*)
insect counts **217** (*298*)
insect damage **502** (*696*)
insect impacts **175, 178, 180, 186, 231** (*224, 225, 231, 236, 240, 241, 272*)
insect mycophagy **250** (*383*)
insect population assessment **183** (*247, 248*)
insect populations **181** (*244*)

insect resistance **200, 558** (*299, 774*)
insect traps **212, 215, 292** (*269, 288, 308*)
insect vectors **250, 275** (*383, 386*)
insecticide evaluation (*313*)
insecticide impact **6** (*344*)
insecticide protection **306, 308** (*327, 329*)
insecticide resistance **302** (*323*)
insecticides **328** (*309, 435*)
insects **14, 355** (*356, 904, 924, 925*)
instrumentation (*20*)
instruments **57, 460** (*158, 159, 161, 162, 163, 535*)
insulation board **725** (*948*)
insurance companies **356** (*929*)
intensive culture **520, 525, 526, 528, 529, 533, 539, 594** (*683, 704, 708, 710, 711, 722, 735, 746, 749, 750, 752, 756, 761, 829*)
intensive management (*546*)
interception **391, 407** (*37, 46, 63, 107*)
intermediate wheatgrass **45** (*145*)
interpretation **109, 110, 111** (*200, 219, 223*)
interpretive exhibits **109** (*223*)
interpretive techniques **112** (*195*)
introgression **447** (*643*)
inventory **517, 726** (*683, 757, 873, 882, 909, 912, 954, 974, 1004*)
investment (*923*)
irradiation **607** (*841*)
irrigation **17, 525, 529, 539** (*13, 17, 708, 749, 752*)
isopods (*301*)
isotopes (*54, 623*)
isozyme patterns (*849*)
Italian stone pine **190** (*362*)

J

jack pine **17, 487, 608** (*17, 672, 850*)
Japanese larch **387** (*32*)
Jeffrey pine **7** (*353*)
job tenure (*1016*)
joints **632, 691** (*1045, 1209*)
June bugs **332** (*565*)
juniper diseases **261** (*411*)
juvenile performance **601** (*824*)
juvenile wood **624** (*1115*)
juvenile-mature correlation **590** (*831, 843*)

K

K-factor (*1208*)
kiln drying **630** (*981, 1087*)
knobcone pine **7, 622** (*353, 853*)

L

labor organization **362** (*940*)
labor productivity (*941, 982, 984*)
labor supervision **571** (*792*)
labor turnover (*1015, 1016*)
laboratory rearing **203, 221, 233, 236** (*253, 259, 287, 301, 303*)
laboratory screening (*313*)
laboratory screening of insecticides **299, 300, 301, 302, 303** (*319, 321, 322, 323, 324*)
laboratory techniques (*547*)
Lake States forestry **336** (*453*)
lakes **99** (*198*)
laminated lumber **632, 655** (*1045, 1077, 1078, 1079*)
laminated products **661** (*1109*)
land management (*100, 913*)
land use **339, 357** (*872, 880, 930*)
land use classification **452** (*336, 878, 907*)
land use conflicts **66** (*173*)
land use planning **65, 66, 102, 103, 398** (*55, 173, 176, 199, 215, 568*)
land values **67** (*177*)
landscape esthetics **63** (*178*)
landscape evaluation **63** (*178, 908*)
landscape management **63, 65** (*176, 178*)
landscape planning **65** (*176*)
landscape preferences **63** (*178*)
landscape quantification **70** (*169, 171*)
landslides (*9, 103*)
larch casebearer **203, 290** (*287, 325*)
large aspen tortrix (*227*)
larvae dispersal **219** (*278*)
lateral stability (*1212*)
lead arsenate **6** (*344*)
leaf discs (*51*)
leaf stomata (*51*)
leases (*928*)
legume (*90*)
levered vehicle **374** (*1025*)
liberation cutting **547** (*767*)
light (*631*)
light traps **183** (*247, 248*)
lightning **458, 462** (*529, 534*)
lignin (*1140, 1159, 1173*)
lignin content **677** (*1157*)
lignin degradation **708, 710, 711** (*463, 465, 466, 467, 468, 1140, 1159*)
lignin detection (*1145*)
lignin digestion **707** (*462*)
lignin formation (*1145*)
lignin-cellulose decay (*1146*)
lignin-enzyme relationships (*1145*)
lime **387** (*32, 94, 95*)
linalool **296** (*331*)
linear models (*1012*)
linear programming **734** (*939, 990*)
literature review (*265, 312*)
littleaf disease **321** (*432*)
livestock management **24, 40, 41** (*129, 139, 149*)
loading and hauling (*1002*)
loamless composts (*951*)
loblolly pine **15, 227, 228, 285, 305, 306, 325, 327, 332, 429, 430, 493, 494, 500, 539, 555, 557, 558, 591, 593, 595, 596, 611, 620, 643** (*5, 19, 113, 232, 268, 273, 328, 329, 345, 393, 399, 400, 407, 444, 445, 448, 461, 565, 587, 588, 668, 670, 752, 766, 773, 774, 796, 811, 812, 823, 846, 857, 1127*)
loblolly-shortleaf pine management **20** (*121*)
lodgepole needle miner **231** (*272*)
lodgepole pine **178, 200, 214, 222, 223, 312, 329, 333, 335, 376, 410, 431, 548, 564, 565, 566, 673** (*224, 225, 252, 254, 285, 296, 299, 334, 440, 454, 563*
lodgepole terminal weevil **214** (*296*)
log and bolt mills (*1014*)
log defects (*983*)
log exports **318, 735** (*441, 980*)
log grade (*987*)
log production (*996*)
log scaling **660** (*1062*)
log storage **721, 722** (*472, 473*)
log volume calculation (*900*)
log weight (*1002*)
logging **56** (*70, 77, 155, 597, 895, 996*)
logging costs **354** (*567, 996*)
logging engineering **382** (*1031*)
logging impacts **36, 229, 382** (*117, 263, 1031*)
logging practices **373, 393, 396** (*53, 71, 1018, 1019, 1027*)
logging production **354** (*567*)
logging residues **346, 373, 376** (*33, 886, 894, 1018, 1019, 1027, 1030*)
logging roads (*8*)
logging systems **365, 376, 384** (*982, 1021, 1023, 1030*)
logs **727, 728** (*960, 962, 963, 964, 965*)
long-term cutting contracts (*928*)
longleaf pine **305, 420, 535, 555, 573, 596, 601, 612** (*328, 571, 644, 715, 766, 795, 812, 824, 847*)
lumber **625, 671, 727, 728, 729, 730** (*936, 949, 958, 959, 960, 962, 963, 964, 965, 966, 967, 968, 969, 1076, 1088, 1094, 1112, 1116*)
lumber and wood products industry (*1004*)
lumber grade recovery **645, 648** (*1082, 1131*)
lumber grading **625** (*1116*)
lumber production (*1004*)
lumber quality (*1088*)
lumber recovery **650** (*1068, 1135*)
lumber value **649** (*1059*)
lumber yields **659** (*1067, 1088, 1102, 1103*)
lumber-plywood mills (*1016*)
lysimeters **394** (*74, 75*)

M

machine planting **530** (*751*)
machining **633, 634, 635, 636, 637, 657** (*1058, 1081, 1121, 1122, 1123, 1125*)
machining properties **627** (*1111*)
malathion **299, 300, 301** (*319, 321, 322*)
management by zoning **90** (*221*)
management information sources **82** (*186*)
management systems **138** (*499*)
maneb **315** (*446*)
manganese (*90*)
manufacturing (*1006*)
manufacturing veneer **665** (*1089*)
maple (*747*)
maple culture **277** (*426*)
maple decline **276** (*394*)
maple sap production **568, 569, 570** (*761, 789, 790, 791*)
mapping **450, 452** (*336, 337*)
marine borers **670** (*1074*)
market analysis **98** (*197, 972, 1003*)
market surveys **95, 97** (*207, 208*)
marketing **97, 730, 733** (*207, 936, 950, 962, 968, 992, 1000*)
marketing models **97** (*207*)
markets **724** (*953, 973, 991, 1003*)
mass fire **160** (*519*)

mass pollination **616** (*863*)
mastic joints **702** (*1203*)
mastics **672** (*1065, 1105*)
mathematical analysis **651** (*1054*)
mathematical model **139, 141, 142, 145, 147, 151, 166, 456** (*494, 495, 502, 503, 505, 511, 512, 521, 533*)
mathematical programming **352** (*919*)
mating behavior **241** (*293*)
meadow development **43** (*147*)
measurement systems (*49*)
measurements **559, 660, 732** (*24, 57, 62, 66, 781, 909, 910, 912, 993, 1062, 1165*)
mechanical pulp **679** (*1154*)
mechanical thinning **507** (*698, 736*)
medicinal plants **120** (*557*)
megalopolis (*935*)
mensuration **550, 557, 560** (*770, 773, 780, 782*)
mental health **80** (*182*)
merchantable volume **545** (*772*)
mercury pollution (*547*)
mesquite control **49** (*135*)
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meteorological stations **460, 461** (*535, 536*)
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pulp properties **640, 677** (*1100, 1157*)
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pulping **628, 679, 683, 684, 685, 686, 708** (*465, 1044, 1060, 1061, 1136, 1137, 1142, 1143, 1144, 1153, 1154, 1156, 1166, 1167*)
pulpwood **344, 353, 366, 368, 371, 683, 684, 686, 725, 728, 736** (*888, 915, 917, 948, 962, 963, 964, 965, 977, 986, 988, 1012, 1035, 1038, 1043, 1137, 1142, 1143, 1144, 1153, 1166, 1167*)

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red oak **680** (*51, 705, 737, 981, 1169*)
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resmethrin **299, 300, 301, 303** (*319, 321, 322, 324*)
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revegetation **390** (*67*)
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root diseases **320** (*405, 433*)
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root exudates **436** (*642*)
root growth **542** (*633, 732*)
root knot nematodes **263** (*414*)
root morphology **442** (*616*)
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root parasites **247, 444** (*118, 610*)
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root rots **197, 244, 246, 264, 322** (*365, 385, 409, 415, 436, 437*)
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sampling designs (*780*)
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sandhill sites **525** (*708*)
sandwich construction (*1199, 1205*)
sandwich panels **689** (*1188, 1200, 1207*)
saprophyte (*639*)
saprophytism (*619*)
sapwood **658, 721, 722** (*472, 473, 1108*)
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sawing **651, 657** (*1054, 1081*)
sawlog conversion **659** (*989, 1067, 1068*)
sawlogs **344, 353, 736** (*888, 900, 915, 936, 977, 986, 987, 988, 1012*)
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sawmilling **659** (*1056, 1067*)
sawmills (*939, 1014*)
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Scotch pine **117, 308, 315, 543, 580** (*327, 446, 450, 554, 733, 827*)
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sediment **405, 406** (*2, 98, 106*)
sedimentation **402** (*87, 92*)
sedimentation basins (*99*)
seed analysis **497** (*688*)
seed and cone insects **182, 183** (*230, 232, 247, 248*)
seed cleaning **480** (*691*)
seed collecting **486, 579** (*684, 822*)
seed dispersal **411** (*573, 574, 575*)
seed dormancy **479, 543** (*666, 673, 733*)
seed drills **478** (*664*)
seed germination **44, 45, 479, 497, 498, 534, 543** (*136, 145, 666, 673, 685, 688, 714, 733*)
seed maturity **486, 492** (*659, 684*)
seed moisture content (*661*)
seed orchards **182, 183, 514, 539, 592, 606, 613, 615, 616, 620** (*230, 247, 248, 752, 754, 806, 838, 848, 857, 860, 863*)
seed predation **445** (*637*)
seed production **420, 514, 579, 605** (*571, 594, 754, 822, 839*)
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seed separator **480** (*691*)
seed source **574, 576, 579, 581** (*115, 799, 815, 819, 822, 826, 832*)
seed source zones **117, 577, 580, 582, 585, 588, 595, 602** (*554, 797, 802, 807, 809, 811, 827, 830*)
seed storage **491, 497** (*658, 688*)
seed testing **534** (*714*)
seed trees **421** (*579, 592*)
seed viability **185** (*233*)
seed yields **330** (*562, 676, 686*)
seedbugs **182, 286** (*230, 416*)
seeding **430, 435, 482** (*588, 634, 665*)
seedling development **470** (*656*)
seedling growth **523** (*721*)
seedling moisture content **516** (*742*)
seedling production **488** (*690*)
seedling survival **431, 485, 496, 513** (*113, 573, 574, 606, 633, 675, 677, 745*)
seedlings **496, 499, 510, 575** (*460, 677, 724, 825*)
seedspot sowing **445** (*637*)
selection cutting **428** (*590, 599*)
selection system **426** (*591*)
senna seymeria **247, 444** (*118, 610*)
sensitivity analysis **734** (*990*)
sequential processes **651** (*1054*)
sequoia pitch moth **137** (*559*)
service life **702** (*1203*)
sewage effluent **17, 18, 19, 640** (*13, 15, 16, 17, 1100*)
sex differentiation in pupae **216** (*270*)
sex pheromone release timing **234** (*260*)
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shade trees **119** (*18, 556*)
sheathing **690** (*1193*)
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shelterbelts **117, 118** (*554, 558*)
shelterwood **412, 421** (*579, 581, 592*)
Sherman big bluegrass **34** (*120*)
shoot damage **180** (*236, 241*)
shoot dieback **193** (*369*)
short logs (*1056*)
shortleaf pine **305, 320, 551, 555, 556, 557, 602** (*19, 112, 113, 232, 328, 433, 766, 768, 771, 773, 830*)
shortleaf pine diseases **321** (*432*)
shrinkage **638** (*1047*)
shrub fruit production **38** (*140*)
shrub management **48** (*144, 146*)
shrubs **42** (*23, 96, 138*)
Shumard oak **491** (*658*)
signal detection analysis **70** (*169, 171, 908*)
silver maple **13** (*349*)
silvics **517** (*601, 604, 618, 622, 628, 630, 636, 638, 640, 757*)
silvicultural characteristics (*640*)
silvicultural control **240, 259, 312, 335** (*290, 403, 440, 454*)
silvicultural conversion **503** (*702*)
silvicultural systems **417, 418, 425** (*569, 572, 593, 596*)
silviculture **422, 429** (*587, 598, 601, 604, 618, 622, 628, 630, 636, 638, 654, 683*)
simulated gas generator **386** (*1036*)
simulation **102, 361, 398, 548, 564, 565, 567** (*55, 215, 769, 784, 787, 788, 938*)
simulation analysis (*56*)
simulation models **88, 103, 383, 384** (*183, 199, 1021, 1032*)
site effects **613** (*848*)
site hazard (*399, 400*)
site index **467, 554, 556** (*655, 762, 768, 903*)
site index curves **468, 549, 554, 555, 556, 562** (*647, 762, 765, 766, 768, 777*)
site preparation **482, 490, 527, 530, 533** (*114, 665, 667, 710, 718, 751*)
site productivity (*654*)
site quality **428, 469, 549, 556** (*599, 652, 735, 765, 768, 1129*)
site value taxation **357** (*930*)
Sitka spruce **687** (*870*)
ski area development **98, 115** (*197, 205*)
skidder tires **385** (*1020*)
skylines **377** (*1026*)
slash **159, 406, 416** (*106, 515, 578, 895*)
slash pine **15, 286, 305, 325, 327, 331, 372, 421, 474, 490, 493, 495, 500, 507, 525, 530, 539, 554, 555, 558, 573, 593, 612, 613, 615, 620, 654, 676** (*328, 345, 416, 444, 445, 448, 452, 461, 564, 579, 644, 657, 667, 668, 671, 698, 708, 751, 752, 762, 766, 774, 795, 823, 847, 848, 857, 860, 864, 1039, 1072, 1172*)
slash--longleaf hybrid **612** (*847*)
slope stability (*103*)
slopes **406** (*8, 106*)
small mammals **60, 75** (*157, 189*)
small tree utilization **655** (*1077, 1078, 1079*)
smaller European elm bark beetle **237** (*257, 284*)
smog damage **8, 9** (*348, 352*)
smoke **122, 123, 124, 156** (*479, 480, 490, 491*)
smoke management **121, 122, 123, 124, 156** (*479, 480, 490, 491, 492*)
smoke yield **692** (*1179*)
smooth brome grass **45** (*145*)
snow **399, 404** (*20, 37, 41, 66, 82, 101*)
snow accumulation **397, 400, 401** (*61, 79, 80*)
snow cover (*42*)
snow damage **502** (*696*)
snow fences **397, 400, 401** (*39, 61, 79, 80, 81*)
snow management (*37, 65*)
snow measurements **394** (*75*)
snowmelt **394** (*37, 56, 75*)
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social indicators **92** (*196*)
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sodium fluoride **629** (*1051*)
softwood lumber (*972, 973*)
softwood volume (*885*)
soil amendments (*952*)
soil analyses (*547*)
soil animals **471, 473** (*648, 653*)
soil biology **251** (*382*)
soil classification **51** (*137*)
soil density (*93*)
soil distribution (*650*)
soil disturbance **115** (*205*)
soil erodibility **1** (*10*)
soil fertility **19** (*15*)
soil frost **396, 403** (*37, 71, 102*)
soil fungi (*360, 428*)
soil geography (*650*)
soil geomorphology (*650*)
soil horizons **43** (*147*)
soil moisture **391, 409, 410, 431, 523, 524** (*63, 74, 93, 110, 570, 606, 631, 721, 726*)
soil moisture potential **45** (*145*)
soil nitrogen **529** (*749*)
soil properties **19, 51, 395, 529** (*15, 30, 137, 729, 735, 749*)
soil reclamation **643** (*1127*)
soil ripping **2** (*1*)
soil splash (*6*)
soil temperature **410** (*24, 36, 570*)
soil testing **532** (*760*)
soil water **395** (*30*)
soil-binding plants (*83*)
soil-plant relationships (*623*)
soil-site relationships **468, 469, 558** (*647, 652, 735, 774*)
soils **74, 343, 575** (*8, 40, 43, 60, 77, 91, 545, 825, 876*)
solar heat **293** (*316*)
solar-powered transmitters **58** (*164*)
solarization **485** (*675*)
solid wastes **681, 682** (*1138, 1155, 1164, 1170*)
Sonderegger pine **596** (*812*)
songbird management **54** (*151, 152*)
sorption theory (*1114*)
sound insulation **703, 704** (*1183, 1186*)
sound transmission (*1176*)
southeastern forest region (*907*)
Southern Forest Insect Work Conference history, 1956-1970 (*302*)

southern hardwoods **442, 443, 528** (*603, 616, 750*)
southern pine beetle **225, 226, 227, 228** (*249, 250, 268, 273, 281*)
southern pine timber management **40** (*149*)
southern pines **247, 288, 326, 444, 508, 527, 528, 538, 540, 555, 616, 629, 652, 653, 656, 669, 679, 685, 688, 730** (*118, 367, 408, 447, 610, 644, 700, 718, 748, 750, 753, 766, 863, 936, 966, 967, 968, 973, 994, 1051, 1066, 1070, 1071, 1076, 1080, 1154, 1156, 1201*)
southwestern pine tip moth **215, 216** (*269, 270*)
sowing **478** (*664*)
spacing studies **481, 509, 559** (*689, 720, 781*)
specialized builders **731** (*1008*)
species comparison **558** (*774*)
species composition **439** (*594, 626*)
species range (*607*)
specific gravity **627, 640, 643, 644, 646, 687** (*870, 1100, 1101, 1110, 1111, 1127*)
spectral radiance data **450** (*337*)
sphagnum **43** (*147*)
splash erosion **1** (*10*)
spoil acidity **388** (*68*)
spoil quality (*97*)
spray application technology (*314*)
spring planting (*96*)
spruce beetle **293** (*274, 316*)
spruce budworm **170** (*226*)
spruce pine **620** (*857*)
stability **121, 662, 663, 677** (*492, 1063, 1084, 1157*)
staining (*869*)
staining rust fungi (*367*)
stand composition (*112*)
stand density **349, 493, 501, 550, 570** (*668, 692, 770, 791, 902*)
stand dynamics **333, 350, 567** (*334, 566, 788*)
stand factors **365** (*1023*)
stand growth acceleration (*926*)
stand improvement **503, 511** (*695, 699, 702, 728, 926*)
stand management (*786*)
stand projection **564** (*787*)
stand structure **439** (*590, 626*)
stand susceptibility **228, 229, 230** (*263, 264, 273*)
stand volume increment **545** (*772*)
stand yield tables **349, 565** (*784, 902*)
starch sugar metabolism **276** (*394*)
state government office furniture (*975*)
statistical analysis **404** (*101*)
statistical samples (*31*)
statistical weighting **557** (*773*)
statistics **150, 164, 455, 456, 457, 463, 465** (*507, 524, 531, 532, 533, 538, 540, 541, 542, 543, 874, 943, 963*)
stem cuttings **614** (*852*)
stem wood **640** (*1100*)
stochastic model **383** (*1032*)
stochastic process **456** (*533*)
stocking **349, 427, 507, 550** (*595, 698, 770, 902*)
stocking equation (*909*)
stocking stand density **551** (*771*)
storage **686** (*1142, 1143, 1144, 1166, 1167*)
storing control (*114*)
storm runoff (*45*)
strawberry leafroller **206** (*280*)
stream chemistry **402, 408** (*92, 111*)
stream discharge **402** (*50, 92*)
stream gaging (*70*)
stream gradient (*99*)
stream management (*76*)
stream temperature **55** (*156*)
streamflow **389, 391, 407** (*47, 49, 63, 64, 77, 105, 107*)
streamflow forecasting (*42*)
streamflow recession (*38*)
streamflow sedimentation **393** (*53*)
streams **3, 406, 408** (*12, 87, 106, 111*)
streamside strip (*104*)
strength **652, 662, 663, 679, 691, 700** (*1063, 1070, 1084, 1154, 1196, 1205, 1208, 1209*)
strength analysis (*1199*)
strength properties **639, 677, 701** (*1064, 1157, 1188, 1197*)
stress (*66*)
stress in forest trees **276** (*394*)
strip mine reclamation **585** (*807*)
strip mine spoils (*93, 94, 96, 97*)
strip mining **402** (*92, 97*)
strip thinning **507** (*698*)
strobili development **526, 535** (*711, 715*)
structural engineering (*1212*)
structural flakeboard **655** (*1077, 1078, 1079*)
structural joint strength **631** (*1128*)
structural lumber (*961*)
structural particleboard **662** (*1084*)
structures **672** (*1065, 1105*)
stump sprouting **546** (*764*)
stumpage **560** (*782, 939*)
stumpage linear programming **361** (*938*)
stumpage price **649, 728** (*955, 956, 963, 964, 965, 1059*)
stumpage sales (*962*)
stylospores (*360*)
subalpine fir **424** (*584*)
subflooring strength **690** (*1193*)
sublimation **401** (*80, 82*)
subsurface flow **407** (*107*)
subterranean termites **714, 716** (*338, 339*)
succession modeling **563** (*783*)
sugar maple **13, 277, 280, 425, 436, 523, 568, 570, 587, 609, 610** (*349, 426, 427, 593, 642, 721, 789, 791, 808, 844, 845*)
sugar maple borer **277** (*426*)
sugar maple decay **282, 569** (*421, 790*)
sugar pine **7, 354** (*353, 567*)
sugarberry (*638*)
sulfur **512** (*740*)
sulfur dioxide **16, 589** (*346, 810*)
sulfur oxides **9** (*348*)
summer camps **104** (*213*)
supply **726** (*913, 917, 932, 970, 972, 973, 974, 998*)
surface area (*78*)
surface checking (*1113*)
surface mining **388, 392, 402** (*68, 86, 92*)
surfactants **506** (*697*)
survey research **106** (*217, 218*)
survey sampling **79** (*190*)
survey trapping **289** (*311*)
surveys (*229, 905*)
survival **601** (*824*)
survival training **80** (*182*)
sustained yield (*596*)
swamp tupelo **441** (*617*)
sweep log bucking (*983*)
sweetgum **534, 598, 614, 617** (*601, 661, 714, 817, 837, 852*)
sycamore **13** (*349, 778*)
symbiotic protozoa **715** (*340*)
synoptic weather systems **454** (*539*)
systemic fungicides **328, 331** (*435, 564*)
systemic insecticides **311** (*306*)
systems analysis **102, 369, 370, 375, 380, 382, 383, 384** (*215, 1021, 1022, 1028, 1029, 1031, 1032, 1041*)
systems modeling **11** (*354*)

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taiga **432** (*615*)
tamarack **416, 639** (*578, 1064*)
taxonomy **47, 205, 206** (*141, 142, 279, 280*)
teaching methods **112** (*195*)
techniques **57** (*158, 159, 161, 162, 163*)
technology **649** (*956, 1059*)
temperature **165, 458, 459, 463** (*514, 530, 534, 540, 707*)
temperature effects **202, 223, 224** (*256, 262, 285*)
tension wood **674** (*866*)
termite damage **716, 723** (*338, 470*)
termite nutrition **714, 715** (*339, 340*)
termites **723** (*470*)
terrestrial microbial ecology (*84*)
test standards **695** (*1185*)
tetrachlorvinphos **301** (*322*)
tetracycline antibiotics **323** (*434*)
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Texas leafcutting ant **295** (*326*)
thermal decomposition (*1200*)
thermistors (*24*)
thermocouple psychrometers (*60*)
thinning **352, 427, 501, 507, 512, 546** (*595, 692, 698, 722, 736, 740, 746, 756, 764, 919*)
timber **353, 359, 361, 726** (*898, 910, 911, 913, 914, 915, 917, 928, 932, 933, 937, 938, 946, 970, 974, 1017*)
timber construction (*1212*)
timber demand (*1068*)
timber growing **351, 352** (*909, 918, 919, 922, 923, 926, 927, 931*)
timber growth **340** (*883, 885*)
timber harvest **340, 728** (*883, 885, 963, 964, 965*)
timber harvesting **364, 389** (*9, 47, 1042*)
timber inventory **342, 345** (*877, 881, 884, 896, 897, 905*)
timber loans **356** (*929*)

timber management **22, 23, 36, 352, 429, 431, 550, 565, 566, 726** (*117, 119, 128, 587, 606, 683, 770, 784, 785, 909, 911, 919, 922, 931, 974*)
timber products **726, 727** (*960, 974*)
timber resources **342** (*873, 880, 881, 885*)
timber supply (*970, 971, 1068*)
timber utilization **656** (*589, 954, 1080*)
tire performance **385** (*1020*)
tissue preparation (*1107*)
titanium sandwich construction (*1205*)
topographic relationships **433** (*608*)
topography (site) **467** (*655*)
Tordon 212 (*701*)
total nitrogen (*547*)
toxic overburden (*97*)
toxicity **3** (*12, 90, 1200*)
tracheid length **640** (*1100*)
trade **727** (*945, 960*)
trail pheromones **295** (*326*)
translocation **518** (*734*)
transpiration (*26, 38*)
transpiration indexes (*51*)
transplanting (*88*)
transportation evaporation **407** (*107*)
transportation systems **374, 375, 381** (*1025, 1028, 1037*)
travel simulation **88** (*183*)
treatability **625** (*1116*)
tree age **561** (*779*)
tree breeding **578, 580, 591, 605, 611, 615, 619** (*796, 813, 827, 839, 840, 846, 854, 855, 860, 861*)
tree breeding methodology **594, 599, 607, 617, 618, 621, 623** (*816, 829, 835, 837, 841, 851, 862*)
tree decay process **281, 282** (*421, 422, 423*)
tree diameter (*955*)
tree diseases **258, 276, 314, 316, 322, 338, 521** (*394, 401, 437, 439, 449, 455, 561, 758*)
tree establishment **387** (*32*)
tree fertilization **6** (*344*)
tree growth **229, 564** (*263, 787*)
tree hazard reduction **114, 334** (*216, 456*)
tree height **549** (*765*)
tree length logs **736** (*977, 982, 986, 988, 1001, 1002, 1012*)
tree maintenance **198, 279** (*371, 372, 424*)
tree mortality **150, 229, 443, 545** (*263, 507, 603, 772*)
tree physiology **541, 576** (*725, 826*)
tree reproduction (*631*)
tree selection (*991*)
tree shakers **372** (*1039*)
tree shaking **495** (*671*)
tree specific gravity **687** (*870*)
tree utilization **653, 656** (*1071, 1080*)
tree value estimates (*1119*)
tree volume estimates (*1119*)
tree weight **644, 654, 656** (*1072, 1080, 1101*)
tree wounds **150, 198, 279, 280, 281** (*371, 372, 407, 422, 423, 424, 427, 458, 507*)
trembling aspen **413** (*580*)
trichlorfon **299, 310** (*305, 319*)
trout habitat management (*99*)
truffles **189** (*153*)
trussed rafters **691** (*1209*)

U

ultrasonic scanner (*1094*)
ultrastructure (*1107*)
urban forestry **67, 119, 521** (*69, 177, 556, 758*)
urban forests **66, 69** (*18, 173, 180*)
urban property **357** (*930*)
urban recreation **66** (*173*)
urban rehabilitation (*999*)
urban wildlife management **52** (*150*)
urea **408** (*111*)
uredinia **255** (*388*)
urine **4** (*14*)
user needs **155** (*498*)
utility poles **61** (*165, 166, 167*)

V

vapor pressure (*1114*)
varnishleaf ceanothus **511** (*728*)
vascular system **518** (*734*)
vegetation **74, 75** (*40, 189, 545*)
vegetation establishment **388, 392** (*68, 86*)
vegetation mapping methods **433** (*608*)
vegetation measurement **57** (*158, 159, 161, 162, 163*)
vegetation monitoring **76** (*188*)
vegetation sampling **76** (*188*)
vegetation type **1, 343** (*10, 876*)
vegetative propagation **489, 544, 603, 609, 610, 612, 614, 620** (*682, 739, 842, 844, 845, 847, 852, 857*)
veneer **661, 665, 667, 676** (*864, 949, 1073, 1076, 1089, 1109*)
veneer dryers **668** (*1090*)
veneer recovery **647, 648, 650** (*1082, 1134, 1135*)
vertebrates **26** (*127*)
vibration transmissibility (*1182*)
vines **42** (*138*)
virgin forests **77, 78** (*184, 193*)
Virginia pine **15, 305, 330, 526** (*328, 345, 562, 711*)
viscometry **162, 163** (*516, 525*)
visibility **454** (*539*)
visitor centers **109, 111** (*200, 223*)
visitor control **88** (*183*)
visual impacts **65** (*176*)
voles **60** (*157*)
volume **341, 342, 353, 601, 628, 637** (*824, 871, 874, 881, 910, 914, 915, 1058 1060, 1136*)
volume formula **660** (*1062*)
volume growth **595** (*811*)
volume increment **466** (*649, 654*)
volume measurement (*956*)
volume table construction **557** (*773*)
volume tables **553, 676** (*763, 864*)
volumetric shrinkage **627** (*1111*)

W

wage differentials (*944*)
wage rates **571** (*792*)
wall strength (*1178*)
walnut bunch **271** (*376*)
walnut insects **171** (*239*)
walnut production **171** (*239*)
waste disposal (*22*)
waste utilization **634** (*1121*)
wastepaper **682** (*1170*)
wastewater **18, 19** (*15, 16*)
water balance (*46, 74, 108*)
water oak **491, 497** (*380, 658, 688*)
water potential (*27*)
water quality **5, 521** (*11, 105, 108, 758*)
water repellency (*33*)
water repellent soils (*3, 4*)
water research (*27*)
water storage (*62*)
water table **536** (*717*)
water temperature (*24, 36, 104*)
water tupelo **310, 441, 491** (*304, 305, 617, 658*)
water yield **397, 405** (*61, 98, 105, 108*)
waterborne salts **670** (*1074*)
watershed management **55, 343, 398, 401** (*29, 43, 49, 55, 56, 77, 80, 156, 876*)
watersheds (*64, 105*)
weather **404, 455, 456** (*101, 533, 541*)
weather modification **399** (*41*)
weather prediction (*48*)
weed control **118, 500, 508, 525** (*461, 558, 662, 700, 701, 708*)
weed seed production **21** (*122*)
weeds **247** (*118*)
weight scaling **353, 736** (*914, 915, 977, 986, 988, 1001, 1012*)
weight tables **553** (*763*)
weirs (*49*)
western blackheaded budworm (*875*)
western cone flower **44** (*136*)
western gall rust **288** (*408*)
western hardwood (*994*)
western hemlock **251, 647, 687** (*382, 551, 870, 1134*)
western larch **180, 483** (*236, 241, 678*)
western pine tip moth **208, 209** (*276, 297*)
western pines **201** (*255*)
western redcedar (*551*)
western shrubs **48** (*144, 146*)
western spruce budworm **179, 180, 210, 224, 302** (*236, 241, 245, 262, 275, 323*)
western tent caterpillar **300** (*321*)
western white pine **191, 256, 258, 578, 605** (*361, 401, 430, 813, 839, 1102, 1119*)
wetlands (*22*)
wetlands forestry **441, 474** (*617, 657*)
wetting agents (*4*)
wetwood **268, 658** (*398, 1108*)
wheat grass (*26*)
wheeled skidders (*982*)
white fir **7, 229, 230, 354, 502, 645, 647** (*246, 263, 264, 353, 567, 574, 696, 1103, 1131, 1134*)
white oak (*981*)
white peachscale **199** (*560*)
white pine **588** (*809, 1099*)
white pine blister rust **254, 255, 256, 257, 336, 578** (*388, 389, 430, 431, 453, 813*)
white pine weevil **176, 221** (*243, 303*)
white rot fungus **709** (*469*)
white spruce **18, 414, 417, 418, 487** (*16, 569, 572, 582, 672, 676*)

white-tailed deer **20, 38, 39** (*121, 140, 148*)
whitefooted mice **220** (*282*)
whole tree utilization **656** (*1080*)
whole-tree chips **368, 369, 370, 371** (*1022, 1029, 1035, 1043*)
wild bird foods **21** (*122*)
wilderness ecology **75, 76, 77, 78, 81, 87** (*184, 187, 188, 189, 193, 194*)
wilderness management **82, 83, 84, 85, 87, 88** (*181, 183, 185, 186, 187, 191*)
wilderness permits **82** (*186*)
wilderness recreation **80, 83, 84, 87, 89** (*181, 182, 187, 191, 211*)
wilderness research **80, 82, 83** (*182, 186, 191*)
wilderness visitor surveys **79** (*190*)
wildfire **77, 78, 81, 135, 462** (*184, 193, 194, 481, 529*)
wildland management (*19*)
wildlife **24, 479** (*129, 673*)
wildlife foods **38, 42** (*138, 140*)
wildlife management **20, 25, 31, 36, 42, 106, 521** (*117, 121, 126, 132, 138, 201, 217, 218, 758*)
wildlife tracking **58** (*164*)
wildlife-livestock interactions **32** (*133*)
wind **165, 453, 454, 463** (*82, 514, 539, 540, 544*)
wind damage **502** (*696*)
wind direction **463** (*540*)
wind modeling **151** (*495*)
wind speed **463** (*540*)
wind stability **502** (*696*)
wind tunnel (*62*)
windbreaks **117, 118, 424** (*554, 558, 584*)
winter damage (*654*)
winter injury **9** (*348*)
winter sports **115** (*205*)
witches'-broom of walnut **274** (*419*)
wood **671, 672, 679, 680, 681, 683, 684, 685, 686** (*1065, 1105, 1107, 1112, 1137, 1138, 1142, 1143, 1144, 1153, 1154, 115*
wood bolts **665** (*1014, 1089*)
wood cells **679** (*1154*)
wood chemistry (*1145*)
wood chip deterioration **366, 706** (*464, 1038*)
wood chip storage **706, 717, 718** (*464, 474, 475*)
wood chips **367, 728** (*962, 963, 964, 965, 1033*)
wood damage control **712** (*341*)
wood damage detection **712, 713** (*341, 342, 343, 423*)
wood decay **195, 198, 266, 278, 279, 280, 281, 337, 708, 709, 710, 711, 714, 719, 720, 723** (*339, 363, 364, 371, 372, 412, 422, 423, 424, 425, 427, 457, 463, 465, 468, 469, 470, 471, 476*)
wood decay fungi **195, 266, 720** (*359, 363, 364, 412, 471*)
wood density **673, 675** (*865, 868*)
wood destroying beetles **712, 713** (*341, 342, 343*)
wood digestion **707** (*462, 466*)
wood drying **638** (*1047*)
wood fiber **674, 679, 680, 681, 683, 684, 685** (*866, 1137, 1138, 1153, 1154, 1155, 1156, 1164, 1169*)
wood flush doors **694** (*1181*)
wood formation **541, 675** (*725, 868*)
wood machining **656** (*1080*)
wood manufacturers (*889*)
wood pallet exchange programs **737** (*1005*)
wood pallet industry (*1011*)
wood pallet parts (*994, 1009, 1056*)
wood pallet production **705** (*994, 1189, 1190, 1191*)
wood pallet quality **705, 737** (*1005, 1010, 1189, 1190, 1191*)
wood pallets **702, 737** (*1005, 1006, 1010, 1203*)
wood preservation **686** (*1142, 1143, 1166*)
wood preservatives **669, 670** (*959, 1066, 1074, 1158*)
wood production **552** (*775*)
wood products **517, 693** (*683, 757, 945, 954, 1184*)
wood products manufacturing (*992*)
wood properties **625, 642, 654, 667** (*607, 805, 998, 1072, 1073, 1116, 1126, 1129*)
wood quality **515, 521, 538, 627, 641, 643, 645, 673** (*723, 748, 758, 865, 1055, 1111, 1127, 1131*)
wood recovery **367** (*1033*)
wood residues **131, 132, 133** (*487, 488, 493, 952*)
wood rot **195, 337** (*363, 364, 457*)
wood storage **721** (*473*)
wood structures **698** (*1195*)
wood ultrastructure (*1099*)
wood use **642, 654, 667, 729, 731** (*957, 958, 969, 1008, 1072, 1073, 1126*)
wood utilization **725** (*948, 961*)
wood waste (*895*)
wooden beverage cases (*976*)
wooden containers (*976*)
woodpecker damage **61, 688** (*165, 166, 167, 1201*)
woodpecker predation (*274*)
woody ornamentals (*405*)
wounded tree reactions **282** (*421*)

X

xerophytes (*620*)

Y

yellow birch **425, 436, 476, 487, 583, 584** (*459, 593, 642, 672, 800, 801*)
yellow-bellied sapsucker **37** (*548*)
yellow-poplar **445, 519, 614, 644, 646** (*51, 637, 661, 705, 706, 852, 1101, 1110*)
yellow-poplar cankers **272, 273** (*395, 396*)
yield regulation **564** (*787*)
yield thinning **551** (*771*)
YMCA **104** (*213*)
young growth **625** (*1116*)
young-growth stands **354** (*567*)
YWCA **104** (*213*)

Z

zygospores (*360*)

2

2,4-D **35, 511** (*130, 728*)
2,4,5-T **506, 511** (*697, 728*)

3

3-P sampling (*905*)

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